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for the Physics Group of the Fast Reactor Project at the Dounreay Experimental Reactor Establishment.

This Group is primarily concerned with experiments on the Dounreay Fast Reactor (D.F.R.) but its responsibilities go further and many of the experiments are designed to increase our general knowledge of fast reactor physics and, in particular, to anticipate problems concerning the design of future fast reactors.

A wide variety of calculations are made of the neutron flux and energy distributions, for a range of core compositions including possible and actual fuel loadings in D.F.R. The scope of the calculations is wide: they may involve simple methods or, for complex solutions, the use of high speed computers.

Theoretical methods are developed and applied to the investigation of the dynamic behaviour of fast reactors generally. The transient neutron flux is determined and used to evaluate thermal transients and finally reactivity transients. The response of the fuel, coolant and structure is computed and finally, the overall reactor characteristic.

D.F.R., previously run at only 1 MW will shortly become the world's highest flux fast reactor, presenting an opportunity to check the accuracy of neutron and gamma shielding calculations, especially for thick shields, and also the effect of the many possible streaming paths for radiation caused by coolant ducts, stepped plugs, etc.

Each of these theoretical programmes is complemented by experiment; e.g. flux distributions are measured in the reactor using fission counters and activation samples. The reactivity oscillator is used to examine the reactor dynamics and this apparatus will require development to improve its accuracy. Special shield plugs incorporating established and recently developed methods for monitoring neutron and gamma fluxes are being constructed.

To support this programme an analogue computer is available and a data link is provided to a " Mercury " computer. Access to a large analogue computer (PACE) and other digital computers is also available.

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BULLETIN
OF
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Thunderstorm Theories

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[A lecture given to the North Eastern Branch in Newcastle upon Tyne on February 20, 1961]

I MUST start with a brief outline of the observational facts about thunderstorms, which must be explained by a satisfactory theory. I have not time to discuss how these facts have been established, but can just enumerate them.

The main separation of charge in a thunder cloud consists of an upper positive charge and a lower negative charge; the average quantities of charge concerned are 20 to 30 coulombs separated by a few km. In addition, there is often, perhaps always, a smaller positive charge still lower in the cloud; although it is thought that this positive charge has an important part to play in the initiation of a lightning discharge, we shall not discuss its origin here—we shall have plenty to occupy the time available if we deal with just the main separation of charge.

The boundary between the upper positive charge and the negative charge usually, perhaps always, occurs where the temperature is well below the freezing-point of water and sometimes even below —20°C. However there is some evidence that lightning, and therefore charge separation, occasionally occurs from clouds which are wholly at temperatures above the freezing-point but there is not yet any evidence whether such clouds are electrically similar to normal thunder clouds, or whether they might just contain the negative and lower positive charges.

A thunder cloud produces an electric field at any point on the ground not too distant. A lightning flash, which on the average moves a charge of about 20 coulombs, gives a sudden change of electric field and after the flash the field recovers towards its pre-flash value. The initial rate of recovery is, on the average, such as to regain the previous value in about 7 seconds, so that it corresponds to a current of about 3 amps; but the recovery slows down and takes an approximately exponential form, suggesting that, as the charges build up, so there are currents tending to dissipate them.

Measurements have been made of the average current above a thunderstorm, to the conducting region in the upper atmosphere and give a result of around 1 amp.

In the separation of charges to give the upper positive and lower negative poles of the thundercloud, we can distinguish two main processes; first, there must be the actual separation of charges from neutral matter with their attachment to particles which move differently, and, second, there must be the different movements of oppositely charged particles, taking them to their appropriate places in the cloud. We can describe these two processes respectively as generation and segregation.

Although it occurs at a later time in the description of the processes at work, it is convenient to consider segregation first. Most of the theories put forward have considered gravitation as the segregating process, so that the earlier process of generation must have resulted in negative charges becoming attached to larger particles than positive charges. (When we are dealing with particles even as large as raindrops we can forget about gravitation giving the same velocities to bodies of different size—it doesn't, because of resisting forces). In this connection, "particles" may be precipitation elements, liquid or solid, cloud droplets or ice crystals, or atmospheric ions, or perhaps particles of sizes intermediate between these classes. So long as the different signs of charge have become attached to particles of different size, segregation is possible. However, it is possible to consider the matter further. After a lightning flash there is a current of around 3 amps and this must be produced by segregation; one cannot expect the generation process to proceed rapidly enough to produce this charge and current at once and we must imagine that the charge has already been generated but not yet segregated. We have a picture of positive and negative charges existing side by side being gradually segregated by gravitation. Clearly the slower the process of segregation the more charge there must be to get the current of 3 amps. It has been calculated by Wormell that if the relative velocities of the two signs reaches 11 m/sec there must be a total unsegregated charge in the cloud of about 1400 coulombs and if the velocity is less the charge becomes greater. The

importance of this result is that if we are to think of negative charges attached to anything smaller than precipitation particles, the total of the charges on these particles would probably be more than they could carry. Thus it looks as though the larger particles in the segregation process must be precipitation particles, if segregation is by gravitation.

There is one theory, however, according to which segregation is not by gravitation. Grenet and Vonnegut have suggested that the positive charges get into a region of the cloud where there is an updraught and negative charges into a region where there is a downdraught. Since the relative velocities may be greater in such a case than for gravitational segregation, the total quantities of charge would be less. But this theory runs into other kinds of difficulty.

Returning now to the theories in which segregation is produced by gravitation, we have already seen that it is probable that precipitation particles are involved, and from the temperatures at the region of charge separation it would seem that the precipitation must be in the solid form.

Several theories have been put forward to account for the generation of charge and we shall have time to consider only some of them. An early theory, which still finds its way into textbooks, is that of Simpson, who considered charge to be generated by the breaking of water drops. A number of workers, including Simpson himself, had found that when water splashes or is broken up by air currents the larger fragments carry a positive charge and there are produced negative ions in the air. This provides a generation of charge, but would give the charges in the thundercloud the wrong way up; also it requires water drops which are not present in the region of the main separation of charge. So Simpson's theory remains of historical interest only, though it might explain the production of the lower positive charge.

A theory of a very different kind was put forward by Wilson. If a water drop is falling in an electric field, it will become polarized; to be specific, suppose it is the fine-weather field, with positive charge above and negative below, then the drop acquires a negative charge on its upper side and a positive below. Ions in the atmosphere will be moving in the field and the upward moving negative ions will be attracted to the lower side of the drop. If the drop is moving downwards more rapidly than the positive ions, these will be repelled from the lower side of the drop and can reach the upper side only when the drop has acquired a negative charge. As a result, the drop gets a negative charge and under suitable conditions there will be a separation of charge. There have been many objections to the theory; one of them, that it depends on liquid drops, is answered by the fact that dielectric polarization of ice crystals would work similarly. Another objection is that the process depends on ions and it is fairly certain that there is not a sufficient rate of production of ions in the volume of a thunder cloud to account for the measured charges and currents, so it would be necessary to assume a fresh production of ions due to the storm. At the present time, Wilson's theory is not considered a serious contender to explain thunderstorm electricity.

The theories which are now most favoured are those which are directly concerned with solid precipitation particles. One theory, put forward by Workman and Reynolds is based on observations of charging when small super-cooled water droplets impinged on a suspended hailstone; it was found that the droplet partly freezes and partly splashes off and that the hailstone acquires a negative charge, while the fragments of water splashing off carry positive charges. It is very difficult to make laboratory conditions close enough to conditions in a cloud to be certain that the same phenomena would occur. A serious difficulty in this theory is that the process would occur only when the temperature is sufficiently close to 0° for the droplet to freeze only partially; at lower temperatures, there would be complete freezing. And, recently, Latham and Mason have found that, when this process occurs, the water splashing off carries a *negative* charge.

When it was first discovered that the main separation of charge in a thunder cloud occurs where the precipitation must be in the form of ice, Simpson and Scrase suggested that the agency generating the charge might be friction of ice particles against one another. It was very difficult to get definite evidence for this process, but eventually Reynolds discovered that when two pieces of ice come into contact, the one that had the higher conductivity gets a negative charge and the other a positive; the mechanism suggested is a transfer of protons, which are the particles responsible for the larger part of the flow of current in ice. Reynolds found that the higher conductivity could be produced either by higher temperature or by the presence of impurities. Reynolds then suggested that, in the region of the thunder cloud where there is separation of charge, there exist together solid precipitation particles, solid cloud particles and super-cooled water droplets. When the super-cooled water droplets impinge on the precipitation particles, latent heat is released on freezing and the precipitation particles are now warmer than the surroundings; thus when the solid cloud particles bounce off the precipitation particles the separation of charge gives a negative charge to the precipitation particles and a positive charge to the smaller cloud particles. Latham and Mason have been able to measure this charging and find that, though it exists and has a magnitude corresponding to theoretical predictions, it is not enough, by a factor of 10^4, to account for the amount of charge in a thunder cloud.

But Latham and Mason have found another effect which is important. When a supercooled water droplet freezes suddenly by impact on a precipitation particle, it freezes first on the outside and then, when the inner liquid freezes, it bursts the skin (as water freezing bursts a pipe) and sends out splinters. Latham and Mason found that these splinters carry away positive charge, leaving the residue, on the precipitation particle, carrying a negative charge; as the ice freezes, the outer part becomes colder than the inner and so gets a positive charge, which is thrown off in the bursting. Measurements have been made of the amount of charge separated for each super-cooled droplet and the calculations show that the effect is just about enough to account for the quantities of charge produced in a thunder cloud.

Of the theories of this type, there seems to be none which can approach this one as a serious contender for the explanation of the main electrical phenomena of a thunder cloud.

We can now return to the theory of Grenet and Vonnegut which attempts to dispense with gravitation as the agency of segregation. Vonnegut makes two important preliminary points: the theories which we have been discussing have been based on the connection of electrification with, first, precipitation and, second, ice; Vonnegut questions these. Although it is certain that there is some connection between electrification and precipitation, Vonnegut puts forward the view that it is the electrification which is the cause of the precipitation rather than the reverse and he gives an account of experiments showing that electrification helps the coagulation of smaller droplets into large. He also puts forward the observations of " warm " thunderstorms, mentioned earlier, as an argument against the connection of electrification with the presence of ice. His picture is that the up-current of a thunderstorm draws in the positive space charge from below the cloud; when this positive charge reaches the top of the cloud it attracts negative charge from above; this negative charge is then caught in down-currents round the edge of the cloud and gets to the bottom of the cloud, where it helps to draw more positive charge into the up-current, and so on, gradually building up charge without needing either precipitation or ice and, at a later stage, using point-discharge current from the ground to supply the positive charge. Vonnegut and his co-workers have attempted to produce a thunder cloud of opposite polarity by feeding in negative charge at the base of a growing cloud, but no conclusive results have yet been obtained. An important argument of theirs is that if precipitation is the vehicle of charge separation then one would expect the precipitation to be highly charged, especially within the cloud and this is not found to be so. There are several arguments against this theory, one of the most serious being that it does not explain why the down-current at the edge of the cloud takes the negative charge from above and not the positive charge which has risen through the cloud, and similarly why the up-current takes the positive charge from below and not the negative charge that has come down round the edges of the cloud.

It appears to be possible to get a criterion to discriminate between the Vonnegut theory and the other type of theory. In Vonnegut's theory, the current of separation of charge is derived from currents outside the cloud and hence we would expect the initial current of the recovery of field after a lightning flash to be less than the current outside the cloud. On the other hand, for theories in which generation takes place inside the cloud, the currents outside are only a part of the current tending to dissipate the generating current and so will be less. The results we have of the generating current from the recovery of field after lightning, and of the external current from flights over thunder clouds are not, unfortunately, for the same clouds or even for clouds in the same locality, so no firm conclusion can be derived at present from this argument, though the results we have are against Vonnegut's theory and in favour of theories of the other type.

Clearly a good deal more needs to be done before we can be sure what are the processes by which a thunder cloud becomes electrified. Since, perhaps, some of my audience may be among those who would ask what good can come of finding out the cause of thunderstorm electrification, I will anticipate the question and point out that there is a great deal of damage done by lightning and by other features of a storm, e.g. hail, which may be associated with lightning, and if we are ever to hope to control a thunderstorm, it is essential to know what causes the electrification before we try to prevent it.

Appeal for the Physics Trust Fund

The following donations or subscriptions were received between July 23 and August 23, 1961:

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The total received in donations or promises (including tax recoverable on covenanted subscriptions) was on August 23, £113,013

Bulletin of The Institute of Physics and The Physical Society

Recent Developments in the Field of Adhesives

G. WINFIELD
Ph.D.

CIBA (A.R.L.) Ltd., Duxford, Cambridge

[A paper given to a symposium on new materials held by the London and Home Counties Branch on November 25th 1960]

INTRODUCTION

THE HISTORY of adhesives dates back to biblical times when gum arabic was in use, and of course animal glue was known before the time of the Pharaohs. Until the turn of the century little attention was devoted to adhesives, although it is interesting to note that guar gum has been grown for centuries in India and Pakistan where the material was used not only as an adhesive filler and sizing agent, but also as fodder for live-stock, and indeed as an item of human diet. However, after a static period of 3,000 years, interest revived in adhesives and the gross deficiencies of natural glues for structural applications stimulated the preparation and investigation of a wide range of synthetic materials.

The gluing of airframe structures initiated a considerable amount of work and in this field the pioneering experiments of N. A. de Bruyne are outstanding. After a relatively short period of research, de Bruyne produced the Redux process of metal bonding and the worth of this technique based on the use of a plasticized phenolic resin has been proved in aircraft all over the world. Perhaps many of us can call to mind the enquiry under Lord Cohen into the accident which occurred to two Comets over the Mediterranean in the early part of 1954. Redux came under rather heavy fire by one witness but Lord Cohen's report completely repudiated any suggestion that the adhesive had failed during the normal conditions to which the aircraft were subjected.

The phenolics and aminoplasts were for many years the most successful of the synthetic structural adhesives but in the late forties the epoxy resins appeared and for general purpose bonding, especially metal to metal, these materials now reign supreme.

Firstly, consider the mechanisms by which bonding may occur.

(i) Perhaps the most familiar is the drying or loss of solvent as in the setting of pastes, mucilages and rubber cements. Heat may be used to expedite the process or room temperature bonding may be effected.

(ii) Pressure-sensitive action is illustrated by certain well known adhesive tapes (Sellotape, Scotch Boy, etc.). These materials have good immediate adhesion but also sufficient immediate cohesive strength to withstand loads. These loads must, of course, be small. The difficulties in formulating a structural adhesive which is pressure sensitive will be dealt with later.

(iii) Another important mechanism is the cooling of hot molten adhesives, for example, hot hide glues for woodworking and a variety of hot melt adhesives used in packaging, bookbinding and labelling. The speed with which a durable bond is formed is of course the great attraction of this type of adhesive. However, of necessity, the material must be thermoplastic and one cannot attain the heat and chemical resistance possible with a thermoset material. This leads to the fourth process, which is particularly important.

(iv) Chemical reaction effecting the polymerization of low molecular weight monomers whereby fully cross-linked and durable polymers are produced in the joint. The chemical reaction may proceed with or without the elimination of low molecular weight fragments. Obviously the latter case is the more desirable since the glue line is placed under no stresses due to the release of volatile matter during the curing of the adhesive.

Having considered the mechanisms by which bonding may occur, the next consideration is obviously the advantages which are gained by the use of these techniques compared with the more conventional methods of attachment, such as riveting and welding. This subject alone cound well occupy the whole of the time allocated to me and I shall do no more than outline some of the more important benefits which are to be derived from the use of adhesives.

(*a*) Certain attachments cannot reasonably be made by any method other than adhesives. For example, the securing of labels to bottles.

(*b*) Smoother contours are available, and this, of course, is especillay valuable for aerodynamic surfaces. Another advantage accruing from the same fact is that one can obtain longer wear in clutch facings and brake linings. It is of interest to note that the first practical application of Redux was in the bonding of clutches for Cromwell and Churchill tanks. The average clutch life was increased from 200 miles for riveted clutches to 2,000 to 3,000 miles for Redux bonded clutches.

(*c*) More efficient and uniform distribution of stresses result from the use of adhesives compared with riveted joints. Again, if I may return to the Comet enquiry, Professor W. J. Duncan in his article " The Comet and Design Against Fatigue " welcomed the use of adhesives of proved reliability on the grounds that they helped to eliminate rivets which are inevitably stress raisers.

(*d*) Less chance of corrosion exists between materials of dissimilar nature. This obviously is a most important factor in the use of adhesives as every major industrial concern loses vast sums of money yearly as a result of corrosion.

(*e*) Adhesives provide better sealing action against gases and liquids compared with riveted joints.

Having indicated some of the general advances in the adhesive field, may I now mention some specific recent achievements.

Eastman 910 Adhesive

The industrial user of adhesives continually asks for materials which set rapidly and which are available for structural service within a very short time of the assembly of the joint. This is an extremely important point for riveting and welding, alternatives in methods of bonding, are both rapid processes and industry must, of course, think in terms of speed of production. Thus there is the need for an adhesive which either:—

(*a*) Cures very rapidly or,
(*b*) Has some measure of instant tack to hold adherends in place while polymerization is occurring.

In this field the adhesive Eastman 910, which is a liquid of low viscosity, represents a most striking advance. This material is a formulated cyanoacrylate resin and the staggeringly short periods of polymerization involved are illustrated in Table 1.

TABLE 1

Gel Times for Eastman 910 Adhesive Cementing Various Materials

Glass/Glass	10-30 seconds
Wood/Wood	3-5 minutes
Steel/Steel	30-60 seconds
Steel/Neoprene	10 seconds
Aluminium/Aluminium	1-2 minutes

Eastman 910 is at its best when used in thin films (50 grams per square metre) and this is undoubtedly due to the accelerating effect of water on the polymerization of the monomer. This system, which is thermoplastic in nature, is typified by good adhesion to metals and plastics, but poor water, chemical and heat resistance. Nevertheless, for effecting high strength bonds in a very short time over small areas, this recent addition to the range of synthetic resin adhesives represents a considerable advance.

'Thermosetting " Quickstick "

Eastman 910 does, as I have indicated, give rise to a thermoplastic bond and there remains the need for an adhesive which has some measure of instant tack but which will produce, on curing, the strength and resilience required for a structural adhesive. The problem really hinges on the fact that it is most difficult to find an uncured synthetic thermosetting resin which has good cohesive strength. In general the molecular weight of the uncured monomer is too low for it to have the cohesive strength necessary for the phenomenon of tack.

I shall now turn to two recent developments which perhaps are of especial interest to this meeting.

Conducting Adhesives

The conductivity of most synthetic resin adhesives is low. Recently adhesives which are thermally and electrically conducting have appeared on the market. Typical values of resistivity and tensile shear strength are shown in Table 2.

These materials are formulated from basic adhesive systems which are heavily filled with metal powders. The characteristics of the adhesive (peel strength, tensile strength, etc.) can in general be modified without any profound effect on the conducting properties of the bond. Obviously this type of material could have many uses, for example, in the repair of printed circuits where soldering cannot be tolerated and in the bonding of lead wires to thin metal plates where the temperature of solder would destroy the plates.

TABLE 2

Typical Properties of Some Conducting Adhesives

Adhesive	*Resistivity (Ohm-CM)*	*Tensile Shear Strength (P.S.I.)*
Hysol 6250	0·01	2000
2 – 73	0·0015	4750
2 – 73A	0·001 0·5 (erratic)	5500

Various workers have suggested the more fundamental approach to this problem of producing synthetic adhesives which are conducting by virtue of their chemical structure, that is, conduction is effected by resonance within the macromolecular framework. This work, however, is very much in the research stage at the present time.

Adhesives for the Construction of Television Sets

The second particularly relevant development concerns the use of adhesives in the construction of television sets. An implosion shield must always be placed between the cathode ray tube and the viewer. Conventionally these shields are situated at a distance of about 1" from the tube. However, if the implosion shield is bonded to the tube, there is no need for the tube to be specially recessed and slimmer cabinet designs are thus possible. Picture quality is also improved by this technique for dust can no longer collect between the tube and shield.

The requirements of the adhesive are that it must gel rapidly and that it must be extremely flexible in order that it can dissipate stresses which might cause picture distortion. A typical system being used for this purpose gels in 10 minutes at 93°C and gives a material which has an elongation, at failure under a tensile load, of over 300%.

Epoxy Resins

Without any doubt the most striking advances in the field of adhesives have been brought about following the introduction of the epoxy resins which are known by several trade and chemical names. The resins themselves may vary in physical form between liquids of moderate viscosity and brittle solids. These substances are of little interest in their thermoplastic state when they exhibit poor mechanical properties. Their enormous possibilities hinge on the variety of methods which can be used to cross link the individual molecules. The resultant macromolecular network provides an adhesive bond of excellent stability chemically, and of good stability thermally, up to temperatures of 100 to 150°C.

The time between mixing of the resin and the curing agent, and gelation of the mixture can be varied between

a few seconds at room temperature, and many hours at elevated temperature. Thus the variation available in usable life of the adhesive is apparent. The type of bond produced can also be varied, for the basic epoxy resins may be modified in a number of ways, e.g. by the use of diluents to effect reduction in viscosity, plasticizers to flexibilize bonds and fillers to dissipate stresses. The epoxy resins also show versatility in their ability to bond a wide range of materials. At their best with aluminium alloys and steel, these compounds also provide high strength bonds to brass, copper and nickel, and are also capable of providing good bonds to lead, polythene, P.T.F.E., P.V.C., and rubber. Typical joint strengths for various adherends are shown in Table 3.

TABLE 3

Typical Joint Strengths Available with Epoxy Resins

Brass	3300 P.S.I.
Copper	3600 P.S.I.
Zinc	1300 P.S.I. (Metal Failure)
P.V.C. (Unprimed)	700 P.S.I.
P.V.C. (Primed)	2400 P.S.I.
Aluminium Alloy	4000 P.S.I.
Polythene (After Flaming)	500 P.S.I.
Perspex	500–700 P.S.I.

The realization that many thermoplastic materials must be chemically treated before satisfactory bonding can occur is of the utmost importance practically and theoretically. The conventional theory of adhesion envisages that bonding occurs because of electrostatic interaction between the adherend and the adhesive. It is obviously difficult to conceive of polythene, for instance, which contains no polar centres, entering into electrostatic interactions. However, if polythene is flamed, it is believed that polar carbonyl groups are produced which can then enter into bonding interactions with a polar adhesive. Certainly the flaming of polythene produces a very considerable increase in the adhesion which can be obtained. Similarly, chemical treatment of P.T.F.E. with sodium in liquid ammonia allows of the production of bonds of moderate strength to this material.

After a critical appraisal of these materials, it soon became evident that the epoxy resins displayed two disadvantages.

The materials were brittle and in addition suffered considerable reduction in bond strength above 150°C. Typical curves for the tensile shear strength/temperature relationship are shown in Figure 1. The brittleness of the material was manifested by poor peel strength and much effort has been devoted to the improvement of this property.

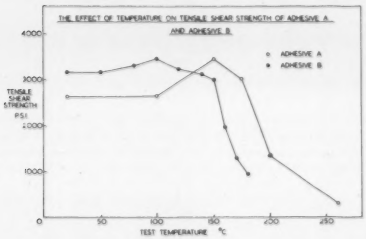


Fig. 1

Now good high temperature properties are generally exhibited by a resin system which has a high density of cross linking. Viewing this concept extremely qualitatively, this means that the distance between points of attachment of the curing agent to the resin is very small, thus there is no "slack" or resilience in the macromolecule which can be used to dissipate stresses set up when the bond is subjected to a peeling load. Conversely, if the density of cross linking is low, then stresses are readily absorbed and dissipated (as for example in rubber). Further, this low density of cross linking generally implies that the high temperature performance of the adhesive will be poor, for the flexibility already present due to the long chains within the macromolecular framework will be further increased by the thermal agitation of the molecule and the adhesive will exhibit low tensile shear strength. This point is illustrated in Figures 2 and 3.

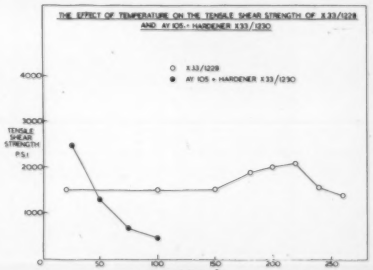


Fig. 2

Figure 2 shows the strength/temperature relationship for two adhesives which differ markedly in density of cross linking. Araldite AY 105 with Hardener X33/1230 has a low density of cross linking and we observe that as the temperature rises above normal ambient, there is a very sharp decline in the tensile shear strength. However, the peel strength of this adhesive is high. X33/1228, which has a high density of cross linking possesses good strength up to 250°C, but is brittle and exhibits low peel strength.

Figure 3 shows the strength/temperature relationships for two pairs of adhesives. Resin X and Resin X′ differ only in molecular weight; the hardener (PMDA) is constant. Resin X′, which has the lower molecular weight, and which gives rise to the more highly cross linked system, exhibits high temperature strengths which are better than Resin X. Resin X however has a superior bend strength (related to peel strength) which reflects the inherently greater flexibility of the

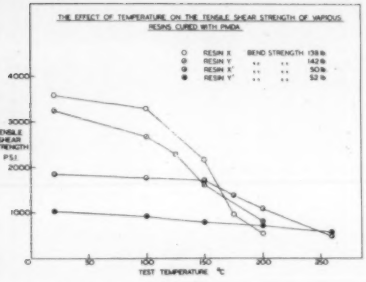


Fig. 3

system. Precisely the same considerations apply to Resins Y and Y'.

Thus there is this fundamental antithesis that a basic resin formulation which exhibits good peel strength usually shows a fairly rapid decrease in tensile shear strength as the temperature rises. To date the most rewarding field of work to combine high temperature strength with peel strength has been in the use of blends of phenolic and epoxy resin.

Figure 4 illustrates the high temperature behaviour of Hidux 1197 A, a phenolic epoxy alloy. This adhesive not only has good peel strength but also exhibits good high temperature performance.

High Temperature Adhesives

The deficiencies of purely organic materials for service at high temperatures are now obvious and an increasing amount of effort is being devoted to the production of semi-organic adhesives and wholly inorganic materials.

Before turning to purely inorganic materials, may I mention briefly the results of a line of investigation which is showing some promise in the high temperature field. This work has been designed to increase the polarity of adhesives. Of course this may well result in increased adhesion but also it may produce a bond which is more stable thermally than one produced from equivalent materials of lower polarity.

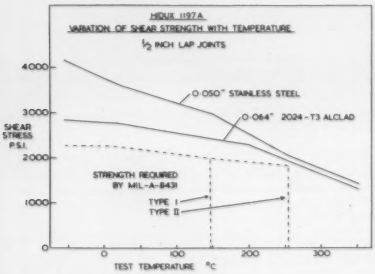


Fig. 4

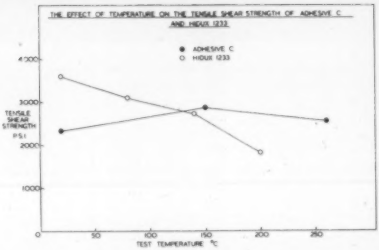


Fig. 5

Figure 5 shows the tensile shear strength/temperature relationships for two adhesives which differ principally in the polarity of the polymer backbone. Hidux 1233—the less polar of the two adhesives—shows good strength values up to 200°C but the effect of increasing the polarity of the backbone (Adhesive C) is self-evident.

The recent Society of Chemical Industry Conference in London revealed that there are many active workers in Britain, America and especially in Russia who have turned their attention to the production of completely inorganic polymers. Several materials have been described, but to date, according to published information, none of these materials have been shown to be workable. However, early this year the Narmco Company in America published information on their work which has led to a means of bonding metals with what is in fact a purely inorganic adhesive.

The two processes disclosed bear a formal resemblance to the classical thermite process and are as follows:—

(1) *Exo-brazing process*

The salient feature of this process is that the temperature needed to heat the adherends to a point where the brazing alloy would melt and form a bond is supplied by a chemical reaction. The source of heat could be a powder mixture of either boron and V_2O_5 or boron and CuO.

(2) *Exo-adhesive process*

In this process, the chemical reaction between the selected materials not only supplies the heat necessary to produce a bond but also supplies the adhesive itself. Oxide-metal and metal-glass systems have been examined. The mixture of reactants can be supplied as a suspension in alcohol which can be painted on to the adherends or as a die-pressed wafer. The assembly is heated to the ignition temperature of the mixture and the ensuing chemical reaction supplies both the additional heat required to wet the metal surface and the adhesive.

In considering recent developments in this challenging field of adhesives, one is compelled to conjecture on future trends. We will surely see developments in the field of high temperature adhesives, and in the realm of general industrial adhesives much work will obviously be devoted to providing easily workable systems which produce durable bonds in an absolute minimum of time.

Notes and News

Harrogate Convention May 23—27 1962

In 1949 The Institute of Physics held the first of its Conventions at Buxton. This new type of meeting was intended to provide an opportunity for physicists of all levels of seniority and of all fields of employment, and their wives, to meet and know each other. The scientific program was varied and was not intended to appeal, as the specialist conference must inevitably do, mainly to the immediate professional interests of those attending. The Convention was very successful and was followed by similar functions in Bournemouth (1953) and Oxford (1957).

Harrogate from the air.

The Council of the Institute and Society has arranged another Convention with the special intention of marking the amalgamation. It will be held in Harrogate on May 23–27, 1962. The scientific program includes a number of Group lectures and two main lectures by Professor A. B. Pippard of Cambridge and Professor Sir Harrie Massey of University College, London. The Guthrie Lecture will also be given during the Convention. The social program will include the Annual Dinner, a Convention Ball and a Civic reception and dance given by the Mayor of Harrogate.

Full details will be circulated to members early next year, but they are asked now to reserve the date. The Council hopes that a large number of members and their ladies will attend; it particularly hopes that younger members and their ladies will take advantage of this unique opportunity to meet other members of the profession.

Fountains Abbey.

The Institute and Society is arranging
a Symposium on

HIGH ENERGY
NUCLEAR PHYSICS

to be held in

The Physics Department of Imperial College of Science & Technology

from

March 26-27, 1962

Several review lectures on both theoretical and experimental topics in high-energy nuclear physics will be included in the program. A limited time will be devoted to short communications. Authors of short papers who would like to be included in the program should send abstracts of their work to Professor C. C. Butler, Physics Dept., Imperial College, London, S.W.7, by January 1, 1962.

It is unlikely that residential accommodation will be available at the College, consequently, intending participants are advised to seek hotel accommodation in good time.

Further details may be obtained from the Administration Assistant of the Institute and Society, during December, 1961.

Safety in Use of Ionizing Radiations: New Code

A safety code for workers exposed to ionizing radiations in industry is laid down in the "Ionizing Radiations (Sealed Sources) Regulations, 1961",* made by the Minister of Labour and presented to Parliament on August 3, 1961.

Most of the requirements will come into operation in six months time, but those requiring the notification of the use and disuse of ionizing radiations in factories became effective from August 15.

The regulations impose requirements for safeguarding the health and safety of persons employed in factories and other places to which the Factories Acts apply, who may be exposed to ionizing radiations from sealed radioactive substances, and from certain machines, such as X-ray apparatus. They require the restriction of the exposure of workers to such radiations, the adequate shielding of sources of ionizing radiations and instructions for workers likely to be exposed to them about the hazards involved and the precautions to be taken.

Maximum permissible doses of radiation are laid down, and the regulations include requirements for the medical supervision of workers, and for the wearing of film badges to measure personal doses received.

The regulations have been drawn up in the light of numerous observations received after the publication of two preliminary drafts and two statutory drafts, and of consultations with organizations of employers, workers and other interested parties. They were also considered by an *ad hoc* expert committee appointed to advise the Chief of Inspector of Factories on the subject, by the Advisory Panel on Radiological Problems in Industry and by the General Purposes Committee of the Radioactive Substances Advisory Committee.

* S.I. No. 1470, H.M. Stationery Office, price 9d. net.

Subscriptions of Members of long standing

Members of 65 years of age who have been members for at least 20 years may, if they so wish, have their future annual subscriptions remitted, but they will then only be entitled to the Institute and Society's publications upon the same special terms as are current for Students.

All members whose subscriptions were remitted under a similar rule of either the Institute or the Society prior to amalgamation automatically continue to have this concession. "Membership" in the rule means full membership of the Institute, the Society or the amalgamated body.

The Institute and Society is arranging a one day Symposium on

Some aspects of vacuum science and technology

at the

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY, LONDON

on

5 JANUARY, 1962

The scope of the symposium will be:

(*a*) Continuously exhausted bakeable vacuum apparatus for pressures below 10^{-9} mm. of mercury.

(*b*) The controlled deposition of evaporated film.

Communications regarding the program should be addressed to the Honorary Symposium Secretary, Mr. D. S. Richards, Department of Mathematics and Physics, The Polytechnic, 309 Regent Street, London, W.1.

Further details and application forms will be available about the end of October, 1961 from the Administration Assistant of the Institute and Society.

X-RAY ANALYSIS GROUP

AUTUMN CONFERENCE

on

IMPERFECTIONS IN CRYSTALS

November 17 and 18, 1961

at

The Institution of Mechanical Engineers, London

Session subjects will be as follows:

The nature of crystal imperfections and of associated diffraction effects.

Experimental methods for studying imperfections. Effects on physical properties.

Included in the invited speakers will be Dr. P. B. Hirsch, F.Inst.P., of the University of Cambridge, and Professor F. C. Frank, O.B.E., F.Inst.P., F.R.S., of the University of Bristol.

Enquiries regarding the program should be addressed to the Honorary Conference Secretary, Dr. G. S. Parry, A.Inst.P., Department of Chemical Engineering, Imperial College of Science and Technology, Prince Consort Road, London, S.W.7.

Registration is necessary. Further particulars and application forms may be obtained from the Administration Assistant of the Institute and Society in early September.

Reviews of Books

OPTICS OF THE ELECTROMAGNETIC SPECTRUM

By C. L. Andrews

London: Prentice-Hall International Inc. Pp. x + 501. Price 63s.

By treating wave optics of " light "—visible, infra-red and ultra-violet—and of micro-waves in one book together, the author wishes to stress the fundamental similarity of phenomena involving waves of widely differing wavelengths. The treatment is essentially elementary, using simple concepts which can be easily visualized, and illustrating more complex theoretical formulae by means of examples. The result is an unorthodox, stimulating and interesting book whose use, in conjunction with other textbooks, can be strongly recommended. Too often the student of physics uses formal mathematical treatments like slot machines, without proper insight into their working. In contrast to this, the author tries to create an elementary but quite intimate acquaintance with the electromagnetic theory of wave propagation, and his attempt is largely successful.

After a survey of the whole field in chapter I, the next chapter deals with wave propagation and includes a lucid, simple treatment of the radiation by accelerated charges. The following chapters deal with the velocity of light and superposition of waves, especially with the formation of standing waves and applications to the field of micro-waves. Chapters VII to XII, on interference and diffraction, form the core of the book. The treatment of diffraction is much more detailed than that to be found in most textbooks. It makes full use of micro-wave experiments, partly those due to the author himself and his co-workers. The treatment of the electro-magnetic theory of absorption, dispersion, polarization and double refraction in the last chapters does not differ greatly from that found in many books.

In the attempt to cover as wide a field as possible, the author has not always succeeded in keeping the quality of the treatment uniform. Micro-waves are clearly closer to the author's heart than light. The difference between the Michelson and the Twyman-Green interferometers is not made clear and such a statement as " . . . lens L_2 focuses the parallel beam to the retina of the eye " is misleading, to say the least. The entirely unimportant condition for minimum deviation for a grating is discussed at length, but the reader is left with the impression that gratings, except for X-rays and infra-red light, are generally used in transmission, and the statement that the spectrum is linear for normal incidence is just wrong. It would have been better to omit such topics as fluorescence, Raman effect and X-ray absorption; they are treated too superficially.

Also the level of the presentation is not always uniform. A reader who needs the elementary treatment of the harmonic oscillator given in 2.2 will scarcely be able to make much of the Fourier transforms in 3.8.

In spite of these shortcomings and some minor mistakes such as the wrong legend under the coloured reproduction facing the title page, the book contains a great deal of good, classical physics presented in a clear, interesting form. The study of many sections of this book could add much to a course on optics and wave motion and can be warmly recommended.

H. G. Kuhn.

TRANSISTORS. PRINCIPLES, DESIGN AND APPLICATIONS

By Wolfgang W. Gärtner

London: D. Van Nostrand Company Ltd. Pp. xii + 675. Price 94s.

How would modern electronics have developed without solid-state devices? It is not until thinking about this that one realizes just how established the semiconductor diode and the transistor have become in the last decade. The rapid expansion of the subject must have posed many problems to the writers of textbooks. Would it be right to assume that the subject has reached a stability such that the fundamentals can now be presented logically, clearly and completely? The recent appearance of this and other well-digested textbooks suggests that this is so.

Dr. Gärtner's book attempts to cover the well-established principles of both transistor physics and applications in a single volume. He should be well qualified in both parts as most of his own original work has been centrally placed, and concerned with transistor characteristics, their explanation in terms of physical processes, and their utilization in circuits. Although this is intended as a textbook for " full year high-undergraduate " or " low graduate " courses, there cannot be many in this country that treat these complementary aspects together. The complete transistor engineer should understand the principles of both parts of the subject, and the clear presentation in this book fulfills this educational task. Few others have covered the whole field so comprehensively for the treatment is both rigorous and detailed.

The first half of the book consists of a thorough introduction to the design of transistors and their characteristics in terms of the material parameters and geometry. After an excellent introduction, the fundamental transport equations for holes and electrons in semiconductors are derived. Transistor design evolves round a discussion of those equations and their application to p-n junctions and multi-junction structures. No more of the pure physics of semiconducting materials is given than is required for the proper understanding of the device topics. Dr. Gärtner is authoritative in deriving the external electrical characteristics of a transistor, with considerable emphasis on the variation of the parameters with bias, frequency and temperature.

It has obviously been difficult to know what to exclude from the early parts of the book. The transistor circuit engineer might be excused from demanding too much from the manufacturers after reading it, as the technological difficulties in actually producing a transistor to a theoretical design are scarcely mentioned. Some of the detailed tables and graphs could have been relegated to appendices to improve the continuity of the text.

The second half of the book constitutes a thorough introduction to transistor circuits. Again the approach is rigorous. After chapters on four-pole theory and bias supplies, a detailed treatment is given of the design approach to a number of basic circuit configurations of amplifiers and oscillators. The inclusion of numerical design calculations is valuable in bringing the theory back to reality. This is not a circuit handbook: the emphasis is on the principles of the subject so that the engineer can design his own circuits for special applications.

The book as a whole should be invaluable to anyone entering either branch of the subject seriously, and particularly to those concerned with matching design to applications. Although not intended as a handbook, the inclusion of a large amount of information in a single volume could make it also a useful reference book in many laboratories.

M. J. Morant.

NUMERICAL METHODS OF CURVE FITTING

By P. G. Guest

London: Cambridge University Press. Pp. xiv+422. Price 80s.

Everyone whose work involves the examination of experimental observations must, at some time, have met the need for curve fitting. The author has collected together those portions of statistics and numerical analysis which are relevant and presented them as a complete subject; the whole forms a compact treatise which should be adequate for most practical needs.

The work is divided into three parts. Part I, which consists of 78 pages, deals with the treatment of observations of a single variable. In fact, it may be described as a brief mathematical derivation of the appropriate statistical tests for single variable. The standard distributions are described and the appropriate tests for means and standard deviations are worked out. Part II, of 62 pages, deals with the well-known regression theory for fitting straight lines. Although much of this may be obtained as special cases from the methods of fitting polynomials, the reviewer welcomes the inclusion of a separate section on the straight line, not only because this is by far the most common example, but also because it gives a useful introduction to the next part of the book for those who are unfamiliar with the subject.

Part III, of 263 pages, deals with the fitting of polynomials and other special curves. This forms the core of the work and is divided into six chapters. These cover Estimation of Polynomial Coefficients, Standard Deviations of the Estimates, Grouping of Observations, Functions which are not Polynomials and General Regression in Several Variables. In order to help those who want a method for a particular problem, the last chapter gives a guide to the most important calculating schemes together with some illustrative examples. Thus they will be guided to the appropriate section of the book with the minimum of delay. However, some people may feel the need of advice from a mathematician before embarking on the complex schemes of Part III. Finally, an eight page bibliography is included to facilitate further reading.

The book is well laid out and contains many methods taken from original papers. Every method is described by deriving the appropriate formulae and is illustrated by a numerical example. In the preface, the author says that the work is intended primarily for students and graduates in physics. The student will benefit by having some aspects of statistics and numerical analysis brought together. So often these subjects are taught with little or no relationship to the physical world. The graduate will benefit by having to hand this summary and guide to the methods currently available for fitting curves. Also, the book will find a place on the shelves of the numerical analyst and statistician as a useful reference book.

A. Huitson.

EDISON

By Matthew Josephson

London: Eyre and Spottiswoode (Publishers) Ltd. Pp. xii+511. Price 42s.

This new biography of Edison is clearly the result of an intensive study of the great pioneer's life story. Many previous misrepresentations and distortions are corrected with nearly seven hundred documentary references. However, the picture given is still essentially that of a youngster of exceptional enthusiasm and interest overcoming great handicaps with tremendous energy and single mindedness to become one of the world's first and perhaps its greatest inventor. As the story develops, we see Edison entangled in the intercompany politics and later developing a keener appreciation of the value of co-operative science, leading him to establishing the first industrial research laboratory of any significance.

The writing is lively and the story fascinating. No doubt Edison lived within the one short span of human years in human history during which one man on his own could contribute so outstandingly to scientific invention. Nevertheless, the great inventor's enthusiasm, his single-minded concentration and his persistence in face of difficulties, which are so well brought out in the volume, should still be a source of great inspiration to our younger generation.

M. F. Haine.

PROGRESS IN DIELECTRICS — Volume 3

Edited by J. B. Birks and J. Hart

London: Heywood and Co. Ltd. Pp. vii+292. Price 63s.

This book is the third of a series of annual surveys of progress in dielectrics. It is the aim of the series to review recent work of interest to the electrical engineer, the physicist, the chemist and biologist.

The first article by Dr. D. G. Kiely of the Royal Naval Scientific Service deals with dielectric wave-guides and aerials in the form of rods and tubes.

The electrical properties of dielectrics in weak fields are discussed in the three subsequent articles: "Theories of Dielectric Polarization and Relaxation" by Professor R. H. Cole of Brown University, U.S.A.; "The Dielectric Properties of Water" by Dr. J. B. Hastead of University College, London; and "Mechanisms of Dielectric Absorption in Solids" by Dr. R. J. Meakins of C.S.I.R.O., Australia.

The next article on " Recent Developments in Cable Insulation in the United States " by C. W. Hamilton of Battelle Memorial Institute, U.S.A., is written from a much more practical standpoint. It deals with the properties of plastic dielectrics such as polyethylene, butyl rubber, and silicone rubber. Although rapid progress is being made in new plastic materials, it is not yet possible for them to compete with the traditional oil-impregnated paper dielectric for high-voltage cables. Incidentally, the article is not quite up to date as far as conventional cables are concerned; it is stated that new designs are suitable for use up to 230 kV and that experimental field installations are planned in the 300/400-kV range. However, 380-kV cable has been in commercial operation in Sweden for several years.

The final article on " The Theory of Dielectric Breakdown in Solids " was prepared by Dr. R. Stratton when he was at A.E.I. Research Department, Manchester. It surveys the breakdown criteria developed by Fröhlich and von Hippel.

It is clear from the standing of the authors that all the articles are authoritative. Much of the information is available elsewhere but it is convenient to have it collected in these volumes. The utility of *Progress in Dielectrics* as a work of reference would, however, be increased if each volume included a summary of every article, a general index, and the list of contents of previous volumes. Perhaps the editors might like to consider these suggestions.

J. S. Forrest.

ANALYTICAL TECHNIQUES FOR NON-LINEAR CONTROL SYSTEMS

By John C. West

London: The English Universities Press Ltd. Pp. 223. Price 25s.

The theory of linear control systems is now well-established and techniques for the design of such systems are well-known, although their industrial use is by no means as widespread as it should be. But, almost as soon as designers began to make use of linear theory, it was realized that it was adequate for only the very simplest applications, and attempts have been made to develop design techniques suitable for use with non-linear systems. This branch of the subject is still developing rapidly and it has not yet reached the stage at which simple design procedures can be laid down. But a number of techniques for the analysis and prediction of non-linear control systems is available and this book describes three of these—the phase-plane technique, the use of the describing function, and the equivalent-gain technique for use with randomly varying input signals.

A more elementary textbook by the same author is now well-known and the present book, which is written in a similar style, forms a companion volume. The author's addiction to the phase-plane technique is clearly shown in both books and, despite the practical limitations of this technique, the description of it and its use occupies almost half the book. The describing function comes a poor second, and the chapters concerned with randomly-varying input signals do little more than introduce this very important branch of the subject. Much of these later chapters is taken up with descriptions of the standard statistical theory involved rather than with specifically control system applications.

In his preface the author states that " the book is written primarily for those control engineers who have felt the need for something over and above the classical theories of linear automatic control systems ". This is, indeed, a fair description of the scope of the book and such readers will certainly find here a useful introduction to non-linear techniques.

The book is reasonably priced but the standard of typesetting is very poor. Some of the mathematical expressions are almost unintelligible and there are one or two rather obvious misprints.

A. E. De Barr.

INTRODUCTION TO ATOMIC ENERGY

By William G. Atkinson

London: Chapman and Hall, Ltd. Pp. vii + 68. Price 11s.

The author of this well-written little book combines (with evident success) the incongruous duties of chief hull designer and instructor in elementary nuclear physics at the Groton Submarine Shipyard where the U.S.S. Nautilus was built. The text is based on lectures given to a variety of part-time students, including housewives, engineers, accountants, salesmen and officers of the Peruvian Navy. The first half of the book deals in elementary fashion with nuclear structure, nuclear reactions and fission. Later chapters discuss the design, construction, operation and uses of nuclear reactors. The treatment is clear, though limited in scope by the exclusion of all but the simplest mathematical aids.

J. M. A. Lenihan.

ENTROPY AND THE UNITY OF KNOWLEDGE

By P. T. Landsberg

Cardiff: The University of Wales Press. Pp. 27. Price 3s. 6d.

This inaugural lecture by Professor Landsberg is interesting to read and it must have been lively to listen to. He shows how the concept of entropy entered physics, traces its development, and hints at its extension to other fields. It was a happy choice to use this outstanding example of conceptualization in science to illustrate the unity of knowledge. As the basis of co-operation between scientists and others, Professor Landsberg rightly rejects the services, such as radio carbon and infra-red photography, which science can provide for the arts man. He suggests that " co-operation could be built on rather deeper foundations: the sharing of specialist ideas, a common intellectual struggle to understand them, the development of common technical concepts".

J. Topping.

MAGNETIC TAPE INSTRUMENTATION

By Gomer L. Davies

London: McGraw-Hill Publishing Co. Ltd. Pp. vii + 263. Price 66s.

The author states in his Preface that the purpose of this book is to act as an introduction to the subject of mag-

netic recording in the field of data recording and processing. He has achieved this object with great success. The book covers very fully all aspects of the subject and is lucidly written. The author is to be congratulated on the extensive bibliography at the end of each chapter, which should make it easy for his readers to obtain all the detailed information which they may require.

The book starts with a brief history of the applications of magnetic tape and then describes the fundamentals of magnetic recording and reproduction. Following this, descriptions are given of the various techniques used for data recording, the various types of tape transport mechanisms, tape motion irregularities, the compensation of flutter and skew errors, and systems for speed control. Then there are chapters on electronic equipment and heads for recording and reproduction. Finally, there is discussion of the various magnetic tape systems and the use of magnetic drums and disks.

A book of this type can fail in its objective because the author, in his desire for simple exposition, leaves out essential information. Mr. Davies is not in this category. He has achieved a nice balance between the conflicting requirements, and has produced a book very easy to read yet packed with all the information necessary to introduce the subject.

Furthermore, the book provides such a comprehensive survey of the subject that there is much of interest in it for anyone concerned with magnetic recording. Many of the systems and methods and all the basic theory are applicable to normal sound recording for speech and music, and would therefore be invaluable for workers in these fields.

T. SOMERVILLE.

Forthcoming Institute and Society Meetings

The following is the list of Institute and Society meetings so far arranged for the first half of the 1961-1962 session. In some cases arrangements are provisional. **Fuller details of each meeting will be sent in due course to the members of the Branch or Group concerned** and may be obtained by other members of the Institute and Society on application to the Secretary. Where it is indicated that registration is necessary early application should be made.

September 18 at 2.30 p.m. AT CAMBRIDGE. Stress Analysis Group.
VISIT to Tube Investments Research Laboratories. Introductory talks by members of the staff on **The growth and shape of whiskers** by J. E. Gordon, and **The strength and mechanical testing of whiskers** by D. M. Marsh.
The visit is strictly limited and registration is necessary.

September 18 at 6.30 p.m. AT MANCHESTER. Manchester and District Branch.
BRANCH CHAIRMAN'S ADDRESS on **A physicist's view of long chain molecules** by Dr. L. R. G. Treloar, F.Inst.P. (*Shirley Institute, Manchester*). At the College of Science and Technology.

September 20 to 22. AT LLANDUDNO. Non-Destructive Testing Group jointly with British Society of Rheology.
CONFERENCE on **Rheological techniques.**
Registration for this conference is necessary. Programs and application forms are available from Dr. P. Lord, A.Inst.P., Royal Technical College, Peel Park, Salford, 5.

September 20 to 22. AT SHRIVENHAM.
SYMPOSIUM on **Some aspects of the physics of space research.** At the Royal Military College of Science.
Registration is necessary.

September 21 at 4.30 p.m. AT BANGOR.
THE GUTHRIE LECTURE of the Institute and Society (to be presented in conjunction with the conference on Radiospectroscopy of solids) on **The de-Haas van Alphen effect and the electronic structure of metals** by Dr. D. Shoenberg, F.R.S. (*University of Cambridge*). At University College of North Wales.

September 21 and 22. AT BANGOR. Jointly with The British Radiospectroscopy Group.
CONFERENCE on **Radiospectroscopy of solids.** At University College of North Wales.
Registration is necessary.

September 23 at 10.00 a.m. AT DURHAM. North Eastern Branch.
SUMMER MEETING. Visits to the New Departments of Pure and Applied Physics, an Organ Factory and a Museum of Oriental Art. At the Science Laboratories.
The visits are limited and registration is necessary.

September 26 at 7.15 p.m. AT GLASGOW. Scottish Branch.
The nature of the bond in metals and alloys by Professor N. F. Mott, F.Inst.P., F.R.S. (*University of Cambridge*). At The University.

September 28 and 29. AT LEAMINGTON SPA. Electronics Group.
CONFERENCE on **The physics of gas discharge devices.** At the Town Hall.
Registration is necessary.

October 5 at 2.30 p.m. At London. Optical Group.
A new cystoscope with improved image quality for vision and colour photography by Dr. H. H. Hopkins, F.Inst.P. (*Imperial College of Science and Technology, London*), and **Light fluctuations and the determination of spectral profiles from fluctuation measurements** by Dr. L. Mandel, A.Inst.P. (*Imperial College of Science and Technology, London*). At Imperial College.

October 6 at 2.30 p.m. At Harmondsworth, Middlesex. London and Home Counties Branch.
Visit to Road Research Laboratory.
Registration is necessary.

October 10 at 5.30 p.m. At London. Electronics Group.
The physics of storage tubes by Mr. B. W. Manley (*Mullard Research Laboratories, Salfords*). At Headquarters.

October 11 at 7.00 p.m. At Liverpool. Liverpool and North Wales Branch.
Large molecules by Professor C. E. H. Bawn, F.R.S. (*University of Liverpool*). At The University.

October 11 at 5.30 p.m. At London. Education Group.
The work of the Royal Institution by Professor R. King, A.Inst.P. (*Royal Institution, London*). At the Royal Institution.

October 13 at 7.00 p.m. At Bristol. South Western Branch.
Thermal vibrations in crystals by Professor Dame Kathleen Lonsdale, F.Inst.P., F.R.S. (*University College, London*). At The University.

October 13 at 11.15 a.m. At London. Applied Spectroscopy Group.
Group Annual General Meeting followed by "Members' Papers" (a series of short papers contributed by members of the Group, mainly on analysis problems). At Headquarters.

October 13 at 6.00 p.m. At London. Non-Destructive Testing Group.
Group Annual General Meeting followed by a lecture on **The relationship between physical properties and structures in metals** by Professor C. R. Tottle, F.Inst.P. (*University of Manchester*). At Headquarters.

October 14 at 11.00 a.m. At Newcastle. North Eastern Branch in conjunction with Department of Extra-Mural Studies.
One-Day Meeting on **New ideas in physics education** by Mr. N. Clarke, F.Inst.P. (*The Institute of Physics and The Physical Society, London*) and others. At King's College.

October 16 at 7.00 p.m. At Manchester. Manchester and District Branch.
The Mössbauer Effect by Professor H. E. Hall (*University of Manchester*). At The University.

October 18 at 6.30 p.m. At Birmingham. Midland Branch.
Branch Annual General Meeting followed by the Chairman's Address at 7.00 p.m. **Musical scales—their characteristics and appreciation** by Mr. M. Milbourn, F.Inst.P. (*Imperial Chemical Industries (Metals Division) Ltd., Birmingham*). At the Engineering Centre.

October 18. At London. Low Temperature Group.
Superconductivity by Dr. P. W. Anderson and **Superconductivity in thin films** by Dr. J. M. Lock (*Royal Radar Establishment, Malvern*). At Headquarters.
Further details will be announced later.

October 20 at 5.15 p.m. At Swansea. South Wales Branch.
Primary cosmic rays by Professor J. G. Wilson, F.Inst.P. (*University of Leeds*). At University College.

October 24 at 2.30 p.m. At London. Stress Analysis Group.
Half-Day Meeting on **The nature of stress raisers.** At Headquarters.
Registration is necessary.

October 25 at 5.30 p.m. At Durham. North Eastern Branch.
The cerebral encoding of optical information by Professor D. M. MacKay, A.Inst.P. (*University College of North Staffordshire, Keele*). At the Science Laboratories.

October 25 at 5.00 p.m. At Hull. Yorkshire Branch.
Nuclear magnetic resonance in solids by Professor E. R. Andrew, F.Inst.P. (*University College of North Wales, Bangor*). At The University.

October 26 at 6.00 p.m. At London. London and Home Counties Branch.
The riddle of the lower stratosphere by Dr. A. W. Brewer, A.Inst.P. (*University of Oxford*). At Headquarters.

October 27. At Glasgow. Scottish Branch (Solid State Group).
Autumn Meeting on **Defects in non-metallic crystals** by Dr. P. Pratt (*Imperial College of Science and Technology, London*) and others. At The University.
Further details will be announced later.

November 3 at 7.00 p.m. At Exeter. South Western Branch.
The Mössbauer effect by Dr. G. Lomer (*Atomic Energy Research Establishment, Harwell*). At The University.

November 8. At London. Low Temperature Group.
Regenerators. At Headquarters.
Details will be announced later.

November 8 at 7.00 p.m. At Liverpool. Liverpool and North Wales Branch.
The moon by Professor Z. Kopal (*University of Manchester*). At The University.

November 8 at 2.00 p.m. At London. Acoustics Group.
Half-Day Symposium on **The transmission of vibrations through the ground** by Dr. N. Ambraseys (*Imperial College of Science and Technology, London*), Mr. H. Pursey (*National Physical Laboratory, Teddington*), Dr. P. N. S. O'Brien (*British Petroleum Ltd., Sunbury*), Dr. A. Bloch, F.Inst.P. (*General Electric Co. Ltd., Wembley*). At Imperial College.

November 9 at 2.30 p.m. At London. Optical Group.
Measurements of the refractive indices of optical materials over the range 0.2μ to 5μ by Mr. A. Jackson (*National Physical Laboratory, Teddington*) and **Report on the Paris Conference** (July 1961) **on optical materials** by Dr. K. M. Greenland, F.Inst.P. (*British Scientific Instrument Research Association, Chislehurst, Kent*). At Imperial College.

November 10 at 6.00 p.m. At Newport. South Wales Branch.
Colour television: principles and practice by Mr. K. Hacking (*British Broadcasting Corporation, London*). At the College of Technology.

November 10 at 2.15 p.m. At London. Non-Destructive Testing Group.
Discussion Meeting on **The role played by dislocation in determining mechanical properties of materials.** At Headquarters.

November 13 at 6.45 p.m. At Manchester. Manchester and District Branch jointly with The Society of Instrument Technology.
The role of the physicist in process control by Dr. L. J. R. Postle, A.Inst.P. (*Wool Industries Research Association, Leeds*). At The University.

November 14 at 5.30 p.m. At London. Electronics Group.
Electron beam parametric amplifiers. At Headquarters. Speaker to be announced later.

November 15 at 6.30 p.m. At Birmingham. Midland Branch.
Problems of information and control in relation to eye-movements by Professor R. W. Ditchburn, F.Inst.P. (*University of Reading*). At The University.

November 15 at 5.00 p.m. At Sheffield. Yorkshire Branch.
Rock magnetism, continental drift and ancient climates by Professor P. M. S. Blackett, F.R.S. (*Imperial College of Science and Technology, London*). At The University.

November 17 and 18. At London. X-ray Analysis Group.
Autumn Conference on **Imperfections in crystals.** At Institution of Mechanical Engineers.
Registration is necessary.

November 20 at 7.00 p.m. At Manchester. Manchester and District Branch.
Neutron diffraction by Dr. G. E. Bacon, F.Inst.P. (*Atomic Energy Research Establishment, Harwell*). At the College of Science and Technology.

November 29 at 6.00 p.m. At Newcastle. North Eastern Branch.
The origin of life in solar systems by Professor J. D. Bernal, F.Inst.P., F.R.S. (*Birkbeck College, London*). At King's College.

November 29 at 5.00 p.m. At Leeds. Yorkshire Branch.
Traffic management in London by Dr. G. Charlesworth, F.Inst.P. (*Ministry of Transport, London*). At The University.

December 6 at 5.30 p.m. At London. Education Group.
The Science Masters Association syllabus by Mr. E. W. Tapper, F.Inst.P. (*University of Bristol*). At Headquarters.

December 8 at 2.30 p.m. At London. Applied Spectroscopy Group.
Recent development on X-ray fluorescence spectroscopy by Dr. J. L. de Vries (*Philips Electrical Ltd., Eindhoven*). At the Royal Aeronautical Society.

December 8 at 2.30 p.m. At London. Electron Microscopy Group.
Report on **Electron microscopy in Japan** by Mr. T. Mulvey (*Associated Electrical Industries Research Laboratory, Aldermaston*) and Dr. M. Whelan, A.Inst.P. (*University of Cambridge*). At Headquarters.

December 8 at 6.00 p.m. At Cardiff. South Wales Branch.
Branch Annual General Meeting followed by a lecture on **Structural studies on fibrous proteins** by Dr. R. E. Burge (*University of London*). At University College.

December 8 at 6.00 p.m. At London. Non-Destructive Testing Group.
The correlation of elastic constants in single crystals and polycrystals by Dr. M. F. Markham (*National Physical Laboratory, Teddington*). At Headquarters.

December 8 at 7.00 p.m. At Bristol. South Western Branch.
Physics in archaeology by Dr. G. N. Fowler (*University of Bristol*). At The University.

December 11 at 2.30 p.m. At London. London and Home Counties Branch.
Static electricity by Dr. P. S. H. Henry, F.Inst.P. (*Shirley Institute, Manchester*). At Headquarters.

December 12 at 6.30 p.m. At Birmingham. Midland Branch.
The observation of radio stars by Dr. P. F. Scott (*University of Cambridge*). At the Midland Institute.

December 12 at 2.30 p.m. At London. Stress Analysis Group.
Half-Day Meeting on **Strain gauges.** At Headquarters.
Registration is necessary.

December 12 at 5.30 p.m. At London. Electronics Group.
Integrated electronics by Dr. J. W. Granville (*Royal Radar Establishment, Malvern*). At Headquarters.

December 13 at 7.00 p.m. At Liverpool. Liverpool and North Wales Branch.
Physics and architecture by Professor J. K. Page (*University of Sheffield*). At The University.

December 13 at 11.00 a.m. At London. Low Temperature Group.
Ferromagnetism and antiferromagnetism. At Headquarters.
Speakers will be announced later.

December 14 at 2.30 p.m. AT LONDON. Optical Group.
A zoom stereoscopic microscope by Mr. T. A. Minns (*W. Watson & Sons Ltd., London*). At Imperial College.

December 14 at 5.30 p.m. AT LONDON. Acoustics Group.
The acoustics of the organ. At Imperial College.
Speaker to be announced later.

December 18 at 7.00 p.m. AT MANCHESTER. Manchester and District Branch.
A musician looks at physics by Mr. F. R. Cox, O.B.E., Hon.R.A.M. (*Royal College of Music*). At The University.

January –. AT GLOUCESTER. South Western Branch.
SCHOOLS' LECTURE on **Automation** by Professor E. B. Pearson, F.Inst.P. (*Royal Military College of Science, Shrivenham*).
Date and time to be announced later.

January 5. AT LONDON.
SYMPOSIUM on **Some aspects of vacuum science and technology.** At Imperial College.
Registration is necessary.

January 10 at 7.00 p.m. AT LIVERPOOL. Liverpool and North Wales Branch.
The physics of computer elements by Dr. C. N. W. Litting, F.Inst.P. (*University of Manchester*). At The University.

January 12. AT LONDON. Non-Destructive Testing Group.
DINNER MEETING followed by an informal address on **Photography** by Dr. H. Baines (*Kodak Ltd., London*). At the "Horseshoe Hotel".
Tickets are necessary.

January 15 at 7.00 p.m. AT MANCHESTER. Manchester and District Branch.
The cosmological problem by Dr. G. J. Whitrow (*Imperial College of Science and Technology, London*). At The University.

January 15 to 19. AT LONDON.
46th Exhibition of scientific instruments and apparatus. At the Royal Horticultural Society's Halls.
Admission by ticket only, available from The Secretary.

January 17 at 2.00 p.m. AT LONDON. Acoustics Group.
SYMPOSIUM on **The calibration of microphones and hydrophones** by Mr. E. Aspinall (*Post Office Research Station, London*) and others. At the Royal Horticultural Hall.

January 17 at 7.00 p.m. AT BRISTOL. South Western Branch.
Irradiation effects in nuclear reactor materials by Mr. R. S. Barnes, F.Inst.P. (*Atomic Energy Research Establishment, Harwell*). At the College of Science and Technology.

January 17 at 2.30 p.m. AT LONDON. Low Temperature Group.
GROUP ANNUAL GENERAL MEETING followed by a lecture on **Crystal lattices of semiconductors at low temperatures** by Dr. D. H. Parkinson (*Royal Radar Establishment, Malvern*) and others. At Headquarters.
Further details to be announced later.

January 17 at 6.30 p.m. AT BIRMINGHAM. Midland Branch.
Development in vehicle and street lighting by Mr. V. J. Jehu, A.Inst.P. (*Road Research Laboratory, Harmondsworth*). At the Engineering and Building Centre.

January 18 at 6.00 p.m. AT LONDON. Stress Analysis Group.
Report on visit to the U.S.A. by Mr. V. M. Hickson, A.Inst.P. (*Royal Aircraft Establishment, Farnborough*). At Headquarters.

January 19 at 6.00 p.m. AT NEWPORT. South Wales Branch.
The limits of perception and measurement by Professor A. M. Taylor, F.Inst.P. (*University of Southampton*). At the College of Technology.

January 25 at 7.00 p.m. AT BRISTOL. South Western Branch jointly with the Institute of Metallurgy.
Recent developments in non-destructive testing by Mr. R. S. Sharpe, A.Inst.P. (*Atomic Energy Research Establishment, Harwell*). At the College of Science and Technology.

January 25 at 6.00 p.m. AT LONDON. London and Home Counties Branch.
LECTURE. At Headquarters.
Details to be announced later.

The Graduateship Examination 1961

THE entry for this year's Graduateship Examination was even larger than would have been expected from the steady rate of increase of the last few years. No doubt this was due to the fact that 1961 was the last year in which the old regulations and syllabuses applied. Under these old regulations over 300 candidates had registered for the examination and eventually 239 actually took the papers. Of these only 64 were successful, which is about the percentage of passes of the last year or two. The names of the successful candidates are given below; those who were awarded a pass with credit will be entitled to apply later for Associateship of the Institute of Physics on the same terms as holders of degrees in physics with first or second class honours.

Pass with Credit

Amery, Bryan Thomas—Thundersley, Essex
(*Municipal College, Southend-on-Sea*)
Farr, Christopher Thomas—Aldershot, Hants.
(*Guildford County Technical College*)
Hughes, Eric Gordon—Walton, Liverpool
(*City of Liverpool College of Technology*)
Trickett, Brian Arthur—Horfield, Bristol
(*Oxford College of Technology*)

Pass

Barratt, Keith Laybourne—Warrington, Lancs.
(*University of Manchester*)
Barton, Clive Edwin—Preston, Lancs.
(*Harris College of Further Education, Preston*)
Bloomfield, Brian—Southend-on-Sea, Essex
(*Municipal College, Southend-on-Sea*)
Bowry, Anthony David—Southend-on-Sea, Essex
(*Municipal College, Southend-on-Sea*)
Burley, Barrington William—Sheffield, Yorks.
(*University of Sheffield*)
Butler, Robert Gyabaa Jones—Wandsworth, London
(*University of Ghana*)
Carter, Albert Clive—Swindon, Wiltshire
(*Oxford College of Technology*)
Cartmell, Michael John—Blackpool, Lancs.
(*University of Manchester*)
Cole, Alan Joseph—Tadley, Hants.
(*Oxford College of Technology*)
Collins, Ronald Charles—Cwmbran, Mon.
(*Newport and Monmouthshire College of Technology*)
Corbett, Shiela Elizabeth (Mrs.)—Leigh-on-Sea, Essex
(*Municipal College, Southend-on-Sea*)
Cox, Anthony Frederick—Isleworth, Middlesex
(*Imperial College, London*)
Crofts, Patricia Elizabeth (Mrs.)—Camberley, Surrey
(*Guildford County Technical College*)
Dancy, David John—Oxford
(*Oxford College of Technology*)
Durling, John Richard—Loughborough, Leics.
(*University College, London*)
Fisher, Joseph Charles—Weymouth, Dorset
(*Imperial College, London*)
Gee, Ronald—Sidcup, Kent
(*Northampton College of Advanced Technology, London, and Borough Polytechnic, London*)
Gleaves, George Henry—Wigan, Lancs.
(*Wigan Mining and Technical College*)
Greene, David Alan—Liverpool, Lancs.
(*City of Liverpool College of Technology*)
Gresley, John Albert Blackwell—Saughall, Chester
(*Royal College of Advanced Technology, Salford*)
Griffiths, Angela Margaret (Mrs.)—Firswood, Manchester
(*Royal College of Advanced Technology, Salford*)
Gumley, Phillip—Ellesmere Port, Cheshire
(*University of Sheffield*)
Hammond, Bruce James—Stevenage, Herts.
(*College of Technology, Letchworth*)
Harness, Ian—Rochdale, Lancs.
(*Royal College of Advanced Technology, Salford*)
Harper, Leslie Richard—Basingstoke, Hants.
(*Reading Technical College*)
Hawkins, Stanley James—Epping Green, Essex
(*The Polytechnic, Regent Street, London*)
Herrington, Brian David—Horsforth, Leeds
(*Leeds College of Technology*)
Hewitt, Anthony Frederick—Tunbridge Wells, Kent
(*Northampton College of Advanced Technology, London*)
Hine, Robert James—Winchester, Hants.
(*Brunel College of Technology, Acton, and Northampton College of Advanced Technology*)
Hodges, Terence Alfred—Abingdon, Bucks.
(*Oxford College of Technology*)
Horbury, Paul Bertrand Holmes—Hull, Yorks.
(*University of Hull*)
Johnson, Colin David—West Bromwich, Staffordshire
(*College of Advanced Technology, Birmingham*)
Lowe, Charles Graham—Stockport, Cheshire
(*Royal College of Advanced Technology, Salford*)
Maddocks, Colin Dean—Stockport, Cheshire
(*University of Manchester*)
McDonald, John Andrew—Great Wakering, Essex
(*Municipal College, Southend-on-Sea*)
Naylor, Peter—Leigh, Lancs.
(*University of Liverpool*)
Neale, Ronald George—Addiscombe, Surrey
(*Croydon Technical College*)
Nicholson, Brian Frederick—Ruislip, Middlesex
(*Brunel College of Technology, Acton*)
Panton, Leslie George Terence—Chester
(*University College, Cardiff*)
Pook, Roger—East Grinstead, Sussex
(*Croydon Technical College*)
Purslow, David—Aldershot, Hants.
(*Guildford County Technical College*)
Rae, William Lillico Stephen—Coatbridge, Lanarkshire
(*Paisley Technical College*)
Robinson, Brian William—Cheadle, Cheshire
(*University of Manchester*)
Rolls, Brian John—Bexley Heath, Kent
(*Northampton College of Advanced Technology, London*)

Shiner, Patrick George—Stourbridge, Worcs.
(*College of Advanced Technology, Birmingham*)
Smith, George Edwin Ian—Wirral, Cheshire
(*University of Sheffield and City of Liverpool College of Technology*)
Smith, Keith—Wirral, Cheshire
(*City of Liverpool College of Technology*)
Spackman, Ramon—Didcot, Berks.
(*University of Exeter*)
Stevens, Derek Clifford—Didcot, Berks.
(*Oxford College of Technology*)
Swain, Thomas Edward—Newcastle-on-Lyme, Staffs.
(*North Staffordshire College of Technology, Stoke-on-Trent*)
Taylor, Eric Royston George—Aldershot, Hants.
(*Guildford County Technical College*)
Tolfree, David William Leonard—Reading, Berks.
(*Oxford College of Technology*)
Triggs, Robert—Farnborough, Hants.
(*Guildford County Technical College*)
Turner, Maurice—Kidderminster, Worcs.
(*College of Advanced Technology, Birmingham*)
Verrall, Alan Frederick Douglas—Bromley, Kent
(*S.E. London Technical College*)
Walford, Francis John—Leigh-on-Sea, Essex
(*Municipal College, Southend-on-Sea*)
Walkden, Michael William—Frimley, Surrey
(*Guildford County Technical College*)
Wheeler, Colin—Aldershot, Hants.
(*Guildford County Technical College*)
White, Brian Malcolm—Harwell, Bucks.
(*Oxford College of Technology*)
Withers, Percy Malcolm—Rickmansworth, Herts.
(*Sir John Cass College, London*)

Two candidates who passed their Physics papers failed in the General paper and will not be eligible for Graduateship until they have either passed this paper or obtained other examination evidence of compliance with the regulations relating to general education.

Tables 1 and 2 below show the qualifications held by the successful candidates in 1961 and in the years 1952-61. Table 3 shows the number of candidates and passes in the individual papers. The question papers are reproduced from page 255 onwards. The Applied Heat paper is included although the candidates entered for it did not attend.

TABLE 1

Number of candidates and passes for the year 1961:—

	No. of candidates	*No. of passes*
Holders of degrees	47	22
Holders of the Higher National Certificate in Applied Physics ...	182	40
Others	10	2
	239	64

TABLE 2

Totals of candidates and passes for the years 1952-1961:—

	No. of candidates	*No. of passes*
Holders of degrees	257	104
Holders of the Higher National Certificate in Applied Physics ...	572	149
Others	64	10
	893	363

TABLE 3

1961 EXAMINATION

	No. of candidates	*No. of passes*
Physics I	194	89
Physics II	175	53
Physics III	32	12
Mathematics I	13	6
Mathematics II	12	3
More Advanced Physics	44	30
Applied Optics	7	4
Electronics	48	22
Mathematical Physics	5	2
Nuclear Instrumentation and Measurements	15	10
Spectroscopy	2	0
Statistics	4	3
X-Rays	4	3
Practical Physics	18	17
General Paper	29	13

This year an examination was also held for Part I of the new regulation Graduateship examination. Holders of a good many pass degrees or the Higher National Certificate in Applied Physics when obtained at sufficiently high standard are exempt from Part I and it is expected that the majority of candidates for Part II, which will be held next year for the first time, will be those who have obtained this exemption. Of the 23 candidates who took Part I only 3 were successful. Details are given in Tables 4 and 5.

TABLE 4

NEW REGULATIONS—PART I

Totals and number of candidates and passes for the year 1961:—

	No. of candidates	*No. of passes*
Holder of degree	1	1
Holders of the Higher National Certificate in Applied Physics ...	17	2
Others	5	0
	23	3

TABLE 5

NEW REGULATIONS—PART I

Passes in individual papers

	No. of candidates	*No. of passes*
Physics I	23	4
Physics II	23	8
Physics III	23	6
Mathematics	23	7
General Paper	1	1

In the opinion of the examiners the standard of the unsuccessful candidates was exceptionally low and few of them appeared to have any real idea of the standard demanded. Part I papers are printed from page 276 onwards. The successful Part I candidates were:—

NEW REGULATIONS—PART I

Pass

Edwards, Vernon William—Didcot, Berks.
(*Oxford College of Technology*)

Hemmings, Peter John—Warrington, Lancs.
(*University of Oxford, and Wigan Mining and Technical College*)

Reeve, Paul Albert—Wantage, Berks.
(*Oxford College of Technology*)

Papers set in the Graduateship Examination 1961

PHYSICS I—GENERAL PHYSICS AND ACOUSTICS

OLD REGULATIONS

Examiner: PROFESSOR J. D. CRAGGS, M.SC., PH.D., F.INST.P.

MONDAY, 5th June—9.30 a.m. to 12.30 p.m.

(*Answer* FIVE *questions*)

1. Give a full treatment of Sabine's theory of reverberation of sound. What factors are important in controlling the reverberation time and how can it be corrected, if necessary, in a concert hall ?

2. What is the Brownian movement ? Derive the relationship between this movement and time, and describe modern studies of this effect.

3. Describe fully how the mass of the earth may be determined. Comment on recent work on the structure of the earth.

4. Write an essay on the production, measurement and applications of ultrasonic vibrations.

5. Explain what is meant by Fourier analysis. Give an example of its application to a particular physical problem.

6. Define group and phase velocities. Illustrate the difference between these with reference to physical situations.

7. Describe fully how to measure the bulk moduli of liquids. Give an account of modern high pressure techniques and briefly mention application to research work in physics.

8. State and explain Stokes' Law.
How is the viscosity of a liquid measured by the rotating cylinder method ?

PHYSICS II—HEAT AND OPTICS
OLD REGULATIONS

Examiner: J. R. ATKINSON, B.A., F.INST.P.

MONDAY, 5th June—2.00 p.m. to 5.00 p.m.

(*Answer* FIVE *questions, at least* TWO *from each section*)

SECTION A

1. Define entropy and develop an expression for the change of entropy when two perfect gases at the same temperature diffuse together. Discuss briefly the meaning and significance of the principle of increase of entropy.

2. Give an account of Debye's theory of the specific heat of isotropic solids. Indicate briefly the way in which the theory can be extended to anisotropic solids.

3. How would you determine the vapour pressure of a metal ?

4. Describe in detail the mode of operation, calibration and practical use of a type of optical pyrometer.

SECTION B

5. Define the cardinal points for a thick lens. A plano-convex lens, of radius of curvature 24 cm and refractive index 1·52, is 2 cm thick measured along the axis. Calculate its focal length and find the position of the image when the object is distant 50 cm from the convex surface (*a*) on the convex side and (*b*) on the plane side.

6. Describe what is meant by " Cornu's Spiral " and explain its use to deduce the nature of the amplitude contours for Fresnel diffraction at a straight edge.

7. Give an account of the theory of the formation of rainbows.

8. Explain the basic principles and use of a type of interferometer and derive an expression for the resolving power of the instrument.

9. Discuss critically the evidence for the belief that light consists of electromagnetic waves.

PHYSICS III—ELECTRICITY AND MAGNETISM
OLD REGULATIONS

Examiner: PROFESSOR J. D. CRAGGS, M.Sc., PH.D., F.INST.P.

THURSDAY, 8th June—9.30 a.m. to 12.30 p.m.

(*Answer* FIVE *questions*)

1. Discuss the phenomena associated with electrical breakdown of gases.

2. Write an account of radioactive transformations. Indicate how knowledge of these may be used to estimate the ages of certain naturally occurring minerals.

3. Describe and explain the operation of a modern form of mass spectrometer.

4. What is meant by para- and dia- magnetism ? How may the magnetic susceptibilities of substances be measured ?

5. Show fully how the inverse square law of charges may be verified experimentally. What is the significance of this law in relation to electrical units ?

6. Write an account of the measurement of electrical power.

7. Give an analytical treatment of forced oscillations in inductively coupled circuits.

8. Describe the absolute determination of the ohm.

MORE ADVANCED PHYSICS

OLD REGULATIONS

Examiner: J. R. ATKINSON, B.A., F.INST.P.

TUESDAY, 6th June—9.30 a.m. to 12.30 p.m.

(*Answer* FOUR *questions*)

1. Outline the essential physics of the recent measurements carried out in an attempt to throw light on the nature of the universe.

2. Explain what is meant by fission and briefly describe the principal components of a power-producing nuclear reactor. How would you proceed to estimate the neutrino flux at a distance of 1 mile from a 100 megawatt reactor.

3. Discuss critically the factors which determine the observed width of a spectral line.

4. Give an account of the special theory of relativity and describe an experiment which supports belief in its validity.

5. Discuss the main concepts which are used to describe the behaviour of electrons in metals and explain why measurements on electrical conductivity are of particular importance in this field.

6. Give a detailed account of what in your opinion has been the most interesting experiment in practical physics that you have carried out. Give reasons for your choice.

7. "As our knowledge of the fundamental nature of matter and radiation increases, the subdivision of Physics into its various sections such as Heat, Light, Sound, Electricity and Magnetism, etc., is becoming increasingly unnecessary". Outline your reasons for agreeing or disagreeing with this statement.

8. Give an account of the phenomena observed in a discharge tube as the pressure is changed and relate these to a theory of the ionization of gases.

APPLIED HEAT

OLD REGULATIONS

Examiners: A. E. De Barr, B.Sc., F.Inst.P., and

Professor M. W. Thring, M.A., F.Inst.P.

TUESDAY, 6th June—2.00 p.m. to 5.00 p.m.

(*Answer* FIVE *questions*)

1. Show how the first and second law of thermodynamics can be used to predict the theoretical limiting efficiency of

(*a*) An internal combustion engine

(*b*) An open cycle gas turbine

Use rough diagrams to illustrate your answer.

2. Calculate the overall rate of increase of entropy where one surface of a flat conducting slab of area A cm^2, initially at temperature T_1, is maintained at T_1°K and the other at T_2°K if the thermal conductivity of a portion of the slab which is at temperature T is $k = \alpha + \beta T$ cal . cm/cm^2 .°C.sec.

3. From the application of thermodynamics, explain with appropriate diagrams whether it is more important to reduce the excess air for combustion, when the combustion gases are used to heat a material at 1600°C or at 100°C ? Apply the same argument to the use of an air preheater heated by the waste gases.

4. Describe in terms of thermodynamics the operation of

(*a*) a heat pump

(*b*) the use of pass out steam for process heating.

Use appropriate diagrams.

5. Discuss critically the methods available for the measurement of temperatures above about 3000°C.

6. Write an essay on either

(*a*) the production of very low temperatures, or

(*b*) thermo-electric refrigeration.

7. (*a*) Explain briefly Prévost's Theory of Exchanges

(*b*) In a tungsten filament lamp it can be assumed that all the energy supplied to the filament is lost by radiation, and that the radiation received by the filament from its surroundings is negligible. If the diameter of the filament is 0·024 cm, its emissivity is 0·3 and the operating temperature is 2450° K, find the length of wire needed in a 100 watt lamp. (Stefan's constant $= 1{\cdot}37 \times 10^{-12}$ cal./(cm^{2}sec (°K)^4); $J = 4{\cdot}2$ joules/cal.)

8. Describe Osborne Reynolds' experiments on the nature of flow of a fluid through a pipe and discuss the results he obtained.

What is the importance of these results in considering heat transfer from a fluid flowing inside a pipe to the pipe wall ?

A hot liquid is flowing through a metal pipe and is cooled by water flowing through a jacket on the outside of the pipe. There is scale on both the inner and outer walls of the pipe. Draw carefully diagrams showing the temperature distribution in a direction perpendicular to the pipe axis when (*a*) both fluids are turbulent, and (*b*) both are moving in streamline flow. Draw separate diagrams for the two cases and comment on the differences in the two diagrams.

9. Describe and explain the operation of

(*a*) An automatic control system for precise control of temperature of a vat of liquid, and

(*b*) An instrument for measuring the oxygen content of boiler flue gases.

APPLIED OPTICS

OLD REGULATIONS

Examiner: C. A. Taylor, D.Sc., F.Inst.P.

TUESDAY, 6th June—2.00 p.m. to 5.00 p.m.

(*Answer question 1 and* four *other questions*)

1. A low-power compound microscope is formed of two thin lenses. The objective has a focal length of 2 cm and is placed at a distance of 2·5 cm from the object. The eye lens has a focal length of 3 cm and the microscope is adjusted so that the final image appears to be in the same plane as the object.

(*a*) Find the separation of the lenses, (*b*) draw the system to scale, and find graphically the angular magnification, (*c*) find graphically the positions of principal planes of the system, (*d*) check (*b*) and (*c*) by calculation.

2. Explain how the axis of a thin converging lens may be found experimentally. Describe in detail the procedure you would adopt to set up an optical system with all its components in accurate alignment. Illustrate your answer by reference to a low-power terrestrial telescope consisting of three thin lenses (an objective, an erecting lens giving unit magnification, and an eye lens) mounted on fully adjustable carriages on an optical bench. You may assume particular constants for the components if you wish.

3. Discuss the essential principles of colour photography, and describe fully one process involving 3-colour separation from the point of view of the physical principles involved (details of necessary chemical processes need not be given). Assume that you are photographing a test-card with red, blue, green, yellow, black, and white patches; describe the appearance of the plates or films at each stage in the process.

4. Write an essay on " The Eye and Vision ", paying special attention to the following topics:— variation of sensitivity with wavelength, variation of colour response with intensity of light, variation of visual acuity with position in the field of view, and visual fatigue effects.

5. It is possible to coat lens surfaces with a layer of dielectric material in such a way that the surface becomes either highly reflecting or almost non-reflecting. Discuss the theory of this phenomenon and explain how the process of coating is carried out in practice.

A film of refractive index 1·3 is deposited on glass of refractive index 1·5; what thickness is required to give minimum reflection for a wavelength of 5890Å ?

6. A number of different photocells is provided and you are asked to compare their sensitivities over the whole range of the visible spectrum. Explain what apparatus you would set up and what experiments you would perform.

7. Discuss and explain the following statements:—

(*a*) If a beam of light is passed through two polarizing screens in succession and one screen is rotated the intensity of the light transmitted varies;

(*b*) If a certain slab of glass is placed between the two screens in (*a*) coloured bands appear in the field of view;

(*c*) A polarizing screen may be used to cut out unwanted reflections in the photography of objects behind glass;

(*d*) If an object is viewed in a certain direction, through a crystal of Iceland spar, the image appears doubled.

8. Explain how you would test the optical perfection of the following for use in precision equipment:—

(*a*) a front-surface aluminized optical flat

(*b*) an equilateral triangular prism

(*c*) a thin converging lens with aspheric surfaces for the correction of spherical aberration.

(9) Explain how you would design (*a*) a two-element composite prism giving deviation without dispersion, (*b*) a two-element composite prism giving dispersion without deviation AND (*c*) a two-element achromatic converging lens to have a given focal length.

Assuming the following constants design a THREE-element cemented prism to be used in a direct vision spectroscope, and calculate its angular dispersion.

Glass 1 refractive index for sodium D line 1·5407; difference between refractive indices for hydrogen F and C lines 0·00910

Glass 2 refractive index for sodium D line 1·6225; difference between refractive indices for hydrogen F and C lines 0·01729.

September 1961

ELECTRONICS

OLD REGULATIONS

Examiner: PROFESSOR M. R. GAVIN, M.B.E., D.Sc., F.INST.P.

TUESDAY, 6th June—2.00 p.m. to 5.00 p.m.

(*Answer* FIVE *questions*)

1. Currents flowing in short multi-turn coils or in long solenoids can be used to focus electron beams. Explain the principles of operation in both cases. Describe one practical application of each.

2. Discuss the nature of the forces on an electron near the surface of a metal and explain how they are related to the work function.

State Richardson's equation for the current emitted by a heated metal. When the work function of the metal changes by a small amount show that the fractional change in emission is proportional to the change in work function and inversely proportional to the operating temperature.

3. In the conventional use of a triode in an amplifier the input circuit is connected between the grid and the cathode and the output circuit is connected between the anode and the cathode. Such an amplifier is called a common-cathode amplifier. Draw circuit diagrams for common-grid and common-anode amplifiers, and explain their special features. Compare the fields of use of these three types of triode amplifier.

4. Give a sufficient account of the physics of the conduction of electricity in gases to explain the operation of the following devices, (*a*) cold-cathode diode, (*b*) hot-cathode mercury vapour diode and (*c*) thyratron.

Explain how a thyratron may be used to provide a unidirectional current from an a.c. supply and show how the mean value of the current may be varied.

5. Negative feedback has numerous advantages such as reduction of distortion and improvement in stability. Name and explain any disadvantages of negative feedback.

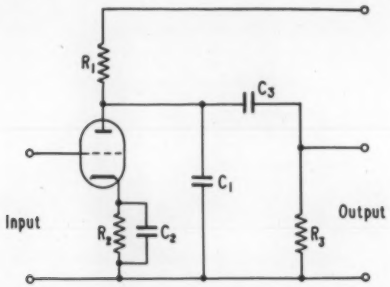
An amplifier without feedback is liable to changes of $\pm 10\%$ in gain as a result of fluctuations in supply voltage. If a feedback amplifier is required to operate from this supply to give a gain of $150 \pm 1\%$ calculate the inherent gain of the amplifier and the feedback factor.

6. Define the hybrid parameters of a transistor. Show that for a common-base transistor amplifier the voltage gain A is given approximately by $A = -R_L/h_{11}$, where h_{11} is the input resistance of the transistor and R_L is the load resistance.

Draw the circuit diagram of a two-stage transistor audio amplifier and indicate suitable values for the components.

7. Write a short essay on klystrons.

8. With reference to the single-stage amplifier shown in the diagram discuss the problems of the amplification of rectangular pulses.



A small rectangular pulse is applied to the input of this circuit. If the amplification factor of the valve is 20, $R_1 = 20{,}000\Omega$, $C_1 = 50$ pF, $r_a = 10{,}000\Omega$ and the effects of R_2, C_2, R_3 and C_3 are neglected, calculate the " rise-time to 90% " of the output pulse. Under what conditions is it permissible to neglect the effect of R_2 and C_2 ?

9. Write explanatory notes on three of the following:

(i) image convertors,

(ii) beat frequency oscillators,

(iii) coincidence counters,

(iv) sodium vapour lamps.

NUCLEAR INSTRUMENTATION AND MEASUREMENT

OLD REGULATIONS

Examiners: A. E. De Barr, B.Sc., F.Inst.P., and D. Greene, B.Sc., Ph.D., A.Inst.P.

TUESDAY, 6th June—2.00 p.m. to 5.00 p.m.

(*Answer* FIVE *questions*)

1. Describe how you would measure the absorption coefficient of a solid material for γ-radiation. Discuss the significance, in this context, of the concept known as " good geometry ".

The linear absorption coefficient for 1 Mev γ-radiation in copper is 0·51 cm^{-1}. Calculate the atomic scattering cross-section.

(The density of copper is 8·8 g cm^{-3} and its Mass Number is 64. Avogadro's Number is 6×10^{23} per g molecule.)

2. Explain the operation of a Geiger counter and discuss the errors that arise in its use.

Devise experiments to demonstrate (*a*) statistical counting errors, (*b*) the effect of resolving time, (*c*) the possible causes of background.

3. Describe a small-scale laboratory neutron source, and discuss the factors that determine the energy of the neutrons.

4. Write an essay on industrial applications of radioactive isotopes.

In an experiment to test the efficiency of a mixing process, a small quantity of radioactive material was added before mixing started. The activities of equal samples were measured at 2-minute intervals after mixing was started, and, after correcting for background, the following figures were obtained:

Time in minutes:	2	4	6	8	10	12	14	16	18	20	22	24	26
Counts in one minute:	507	560	667	610	495	490	473	427	415	367	342	340	310

The half life of the radioactive isotope used was 20 minutes. What was the time required to achieve a uniform mixture ?

5. Describe a modern form of mass spectrograph and discuss its use to determine atomic masses.

Comment on the relationship between atomic mass and atomic number.

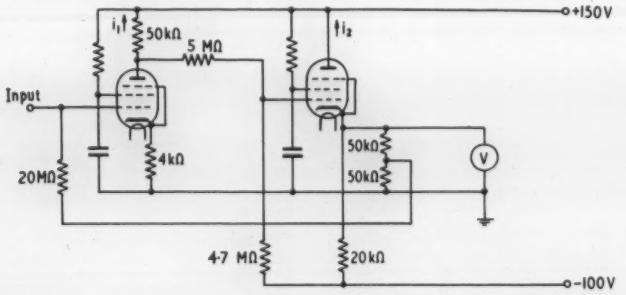
6. Define (*a*) the roentgen, (*b*) the rad and (*c*) the curie. Describe in detail an absolute method of measuring a dose in roentgens.

7. Describe the desirable properties of an electrometer valve and discuss its uses.

Compare the relative merits of thermionic valve and other methods of measuring very small currents.

8. Give an account of the physical phenomena utilized in the use of photographic emulsions for the study of nuclear reactions.

9. Discuss the properties and possible applications of the amplifier circuit shown.



Calculate the anode and grid voltages relative to the cathode of each valve when the output meter indicates zero, the anode currents being: $i_1 = 1$ mA. : $i_2 = 5$ mA. Determine the voltage gain of the amplifier.

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SPECTROSCOPY

OLD REGULATIONS

Examiners: A. E. De Barr, B.Sc., F.Inst.P., and M. Milbourn, B.Sc., F.Inst.P.

TUESDAY, 6th June—2.00 p.m. to 5.00 p.m.

(*Answer* FIVE *questions, at least* TWO *from each section*)

SECTION A

1. A concave reflection grating has a radius of curvature of 3 metres and is ruled with 10,000 lines per centimetre over a width of 5 centimetres. It is placed in a Rowland mounting and a first order spectrum is photographed. What is the linear distance in the spectrogram between two lines of wave length 3130·2 Å and 3134·7 Å ? If one of these lines has two components separated by 0·05 Å, would they be separately identified in the spectrogram ? Derive any formulae used.

2. What devices (other than photographic emulsions) are used for measuring the intensities of radiations in various ranges of the electromagnetic spectrum ? Choose any one of these devices and indicate (*a*) the theory of its operation, (*b*) any electrical circuits that may be needed for effecting measurements, (*c*) its sensitivity and accuracy and (*d*) the precautions required in using it.

3. The following results were obtained in similar absorptiometric tests on a series of solutions containing increasing amounts of an absorbing constituent:—

% constituent	0·00	0·10	0·20	0·50	0·70	1·00	1·50	2·00
Intensity of transmitted beam	100	90·6	83·5	62·7	52·5	40·9	27·4	19·4

Discuss these results with reference to the Lambert-Beer law, indicating whether they conform to it, and the possible reasons for departure if they do not.

Sketch the optical system of an instrument suitable for making these measurements, given that the absorbing constituent has an absorption band from 5230 Å to 5450 Å.

SECTION B

4. Write notes on three of the following:

(*a*) Raman spectra

(*b*) Atomic absorption spectroscopy

(*c*) Thermal excitation

(*d*) Sources for infra-red absorption investigations

(*e*) Monochromators of large aperture

(*f*) Nuclear magnetic resonance spectroscopy.

5. Describe briefly the historical development of either (*a*) stellar spectroscopy, or (*b*) sources for emission spectroscopy.

6. Discuss methods for applying corrections for the effects of continuous background in photographed spectra. Include any relevant photographic theory.

7. Outline theoretical aspects of the absorption of radiation by molecules. Indicate the types of information obtained from absorption data in various ranges of the electromagnetic spectrum, and illustrate by reference to specific examples.

8. Discuss the estimation of temperatures by means of spectral measurements.

9. Indicate briefly the theory of excitation of X-ray spectra, and of the means adopted for effecting excitation and dispersion. Exemplify by reference to any one technique employing X-ray spectra for analytical purposes.

X-RAYS

OLD REGULATIONS

Examiners: A. E. De Barr, B.Sc., F.Inst.P., and R. F. Farr, M.A., F.Inst.P.

TUESDAY, 6th June—2.00 p.m. to 5.00 p.m.

(*Answer question 1 and any* four *others*)

(*The required numerical data are given at the end of the paper*)

1. Distinguish between the roentgen, the rad and the rem.

Explain carefully what is meant by maximum permissible dose and give examples of the values of this quantity. If a worker is consistently exposed to the maximum permissible dose from the age of 18, what dose will his gonads have accumulated by the age of 30 and his bone marrow by the age of 65. Explain the significance of these quantities.

An 18-year old worker is employed on a variety of work and wears a film badge which records the following doses in consecutive weeks: 150, 150, 200, 100, 100, 400, 175, 125, 125, 100, 50, 125, 50 millirem. In the next quarter he receives a total dose of 3·4 rems.

Comment on these figures.

2. Explain the influence upon the intensity and quality of the radiation emitted by an X-ray tube of variations of (*a*) the current of electrons striking the target, (*b*) the potential difference between cathode and anode.

Draw a circuit diagram of an X-ray generator, and show clearly how (*a*) the tube current, and (*b*) the potential between the electrodes are both controlled and indicated. Explain any circumstances under which the meters may not give a true indication of these two quantities.

What other controls and meters are usually provided on an X-ray set ?

3. What is meant by an " air-equivalent wall " of an ionization chamber ? Explain carefully its significance for the measurement of dose in roentgens.

An ionization chamber has an air-equivalent wall and an effective air volume of 120 cm^3. It forms part of a condenser-chamber having a total capacity of 50$\mu\mu$F. The condenser-chamber is charged to a potential of 450 volts and placed 50 cm from a radiographic source of effective strength 150 milli-

curies. After 30 minutes have elapsed, the potential has fallen to 160 volts. Estimate the K-factor for the radio-isotope used.

4. Explain the exponential law of absorption of X-rays and discuss the conditions under which it holds. Define half-value layer, and describe the experimental arrangement necessary for its accurate determination.

A dose-rate meter was placed 75 cm from the target of an X-ray tube operated under fixed conditions. The dose-rate was measured with different numbers of aluminium plates, each 0·5 mm thick, interposed between the tube and the dose-rate meter. The results obtained were:

No. of plates:	0	1	2	4	6	8	10	12
Dose, r/min:	92	63	51	37	31	26	23	19

Comment on these results and compare (*a*) the dose-rates at a distance of 75 cm from the target, and (*b*) the half-value layers, (i) when the beam is unfiltered and (ii) when a filter of 1·5 mm of aluminium is used.

5. Give an account of Compton scattering of X-rays. Make special reference to the influence upon the intensity and the quality or wavelength of the scattered radiation of (i) the wavelength of the primary radiation, (ii) the direction in which the scattered radiation is measured, (iii) the nature of the scattering material.

An X-ray photon of energy 125 keV is scattered, in the Compton process, at right angles to its original direction of travel. Estimate the energy of the scattered photon and account for the difference in the energies of the primary and scattered photons.

6. Give an account of fluorescence induced by X-rays, with special reference to the intensity and colour of the light emitted. Compare and contrast the effects of light and X-rays on a photographic emulsion, and explain the use of intensifying screens.

Explain why structures may sometimes be visible on a radiograph but not on a fluoroscopic screen.

Discuss the selection of screens for radiography and for fluoroscopy with special reference to (i) spectral sensitivity, (ii) grain size and thickness of coating.

7. Explain fully the meaning of the statements:

(*a*) The wavelength of cobalt $K\alpha_1$ radiation is 1·789 Å.

(*b*) Cobalt-60 decays with a half life of 5·25 years, and emits γ-rays of energies 1·17 and 1·33 MeV.

What are the desirable features of a radioactive source used for γ-radiography ?

A γ-ray source is placed 2 metres from a wall which is 50 cm thick. When the beam of radiation is directed normally at the wall the dose-rates at the two faces of the wall are 1·6 r/hour and 1 mr/hour. If the source is turned so that the beam is now incident at an angle of 45° to the wall, estimate the dose rate on the far side of the wall.

8. Explain carefully how X-rays can be used to investigate

(*a*) the arrangement

(*b*) the size

(*c*) the condition

of the crystallites in polycrystalline solids.

9. Explain, with reference to the diffraction of X-rays by a single crystal of a substance of large molecular weight, what is meant by the term " structure factor ".

Explain how the structure of such a crystal may be determined from measurements of the intensities of the diffracted beams.

Numerical data

Planck's constant, h	$6{\cdot}6 \cdot 10^{-27}$ erg sec
Velocity of electromagnetic waves in free space, c	$3 \cdot 10^{10}$ cm sec^{-1}
Electronic mass, m	$9{\cdot}1 \cdot 10^{-28}$ g
Electronic charge, e	$4{\cdot}8 \cdot 10^{-10}$ e.s.u.
Electrostatic unit of potential difference	300 volts.

MATHEMATICAL PHYSICS

OLD REGULATIONS

Examiner: A. W. GILLIES, B.Sc., PH.D., F.INST.P.

TUESDAY, 6th June—2.00 p.m. to 5.00 p.m.

(*Answer* FOUR *questions*)

1. A string of length $4l$ is stretched tightly with tension T between two fixed points. Three particles, each of mass m, are attached to the string at equal distances from each other and from the ends. Determine the equations of motion for small transverse vibrations and show that the characteristic frequencies are given by

$$\omega_1^2 = \frac{T}{ml}(2+\sqrt{2})$$

$$\omega_2^2 = \frac{T}{ml} \cdot 2$$

$$\omega_3^2 = \frac{T}{ml}(2-\sqrt{2})$$

Determine the relative motions of the particles for the oscillation of intermediate frequency. Give a set of initial conditions such that this mode only would be produced.

2. A bead slides freely on a circular loop of wire of radius a while the wire rotates about a vertical diameter with constant angular velocity ω.

Take the angle θ between the radius to the bead and the downward vertical as co-ordinate, and use Lagrange's method to obtain the equation of motion of the bead in the form

$$\ddot{\theta} - \omega^2 \sin\theta \cos\theta + \frac{g}{a}\sin\theta = 0$$

Examine the number and stability of the equilibrium positions for $\omega^2 < g/a$ and for $\omega^2 > g/a$ and determine the periods of small oscillations about the positions of stable equilibrium.

3. A uniform plate bounded by planes $x=0$ and $x=l$ is made of material of thermal conductivity k, density ρ, and specific heat c. At time $t=0$ the temperature θ varies uniformly from $\theta=0$ at $x=0$ to $\theta=\Theta$ at $x=l$. The temperature of the face $x=l$ is then suddenly reduced to zero and is maintained at zero. Determine how the temperature in the plate varies during the subsequent cooling.

If $k=10^{-3}$, $c=1$, $\rho=2{\cdot}5$ and $l=2\pi$, estimate the time required for the temperature at the centre section to fall to half its original value.

4. Liquid of viscosity μ occupies the space bounded by parallel planes $z=0$, $z=h$. The pressure is constant over planes parallel to the yz plane but there is a pressure gradient in the x-direction. Show that if the flow is steady this pressure gradient is constant. Determine the quantity of liquid flowing in the x-direction per unit time and per unit length in the y direction, and also the force per unit area of each of the bounding surfaces.

5. Laplace's equation in cylindrical co-ordinates (r, θ, z) is

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial V}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 V}{\partial \theta^2}+\frac{\partial^2 V}{\partial z^2}=0$$

Investigate solutions of the form $V=R\Theta$ where R is a function of r only, and Θ is a function of θ only, V being independent of z.

A uniform electrostatic field $E\mathbf{i}$ exists in a certain region of space. Determine the distortion of the field when a long cylinder of radius a, and of uniform material of dielectric constant (relative permittivity) k, is placed with its axis along the z-axis. Treat the field as two dimensional. Show in particular that the field in the cylinder is uniform and of intensity $2E/(k+1)$.

6. The only electrically charged bodies in a certain field are two conductors A and B. When A is earthed and B is maintained at potential V, A acquires a charge Q. Prove that if B is earthed and A is maintained at potential V, then B will acquire an equal charge Q.

If A surrounds B and they are maintained at potentials V_a, V_b respectively the potential at a certain point P in the space between them is V_p. The conductors are now both earthed and a point charge of magnitude Q is placed at P. Prove that the charges Q_a, Q_b acquired by the conductors satisfy

$$\frac{Q_a}{V_b-V_p}=\frac{Q_b}{V_p-V_a}=\frac{Q}{V_a-V_b}$$

7. Current flows in the direction of the x-axis in a semi-infinite conductor of conductance σ bounded by the xy plane, with $z>0$ in the conductor. Assuming that current density $\mathbf{j}$ and electric field $\mathbf{E}$ are in the x direction, that they are independent of y and depend on t only through the factor $e^{i\omega t}$, apply Maxwell's equations to obtain $\mathbf{J}$, $\mathbf{E}$, $\mathbf{H}$ at depth z in terms of their values at the surface. It may be assumed that displacement currents are negligible in comparison with conduction currents.

8. The wave equation for a hydrogen atom is

$$\nabla^2\Psi+\frac{8\pi^2 m}{h^2}\left(E+\frac{e^2}{r}\right)\Psi=0$$

Show that this equation has a spherically symmetrical solution of the form $\Psi(r)=e^{-ar}$ where a is a constant to be determined.

Discuss this solution in relation to the Bohr theory of the ground state of the hydrogen atom.

9. Two rods which are parallel to each other move relatively to each other in their length directions. Explain why it is possible that either rod may appear longer than the other, depending on the state of motion of the observer.

September 1961

STATISTICS

OLD REGULATIONS

Examiner: E. D. VAN REST, M.A., B.Sc., F.INST.P.

TUESDAY, 6th June—2.00 p.m. to 5.00 p.m.

(*Answer* FOUR *questions*)

1. Discuss briefly TWO of the following:—

   (*a*) The two types of error associated with hypothesis testing.

   (*b*) Regression analyses and the dangers in their interpretation.

   (*c*) The use of range as a measure of dispersion.

   (*d*) The importance of random allocations in experimental design.

2. Give a general account of the purpose of a significance test and the logical steps in its use. Illustrate your answer by reference to the following problem.

A new method is proposed for determining the melting point of metals. The method is tested by estimating the melting point of iron, the true value of which is known to be 1535°C. The following eight readings were obtained:—1537, 1541, 1536, 1545, 1533, 1540, 1541, 1539. Do these readings indicate that the method is biased ? If so give a 95% confidence interval for the extent of the bias.

3. A specification reads as follows:—

" Test a sample of 20. If there are no rejects, pass the batch. If there are two or more rejects, fail the batch. If there is one reject, test a further sample of 10; pass if there are no rejects and fail otherwise ".

Draw the operating characteristic curve for:

   (*a*) The first test only.

   (*b*) The combined results of the first and second tests.

4. Under what conditions would you expect a random variable to follow a Poisson distribution? Give two examples. Prove that the mean for such a distribution is equal to the square of the standard deviation.

The number of hits registered in T seconds by a Geiger counter may be assumed to follow a Poisson distribution with mean λT, where λ is a constant depending on the strength of the source. Duplicate readings were made using the same source; 60 hits were registered in 30 seconds and 129 were registered in 60 seconds. Use these figures to obtain an unbiased estimate of λ with minimum variance (Hint: let r_1 = number of hits in 30 seconds and r_2 = number of hits in 60 seconds and find weights w_1 and w_2 such that $w_1 r_1 + w_2 r_2$ is an unbiased estimate of λ with minimum variance).

5. As a check on the strength of some large castings, a small test-piece was produced at the same time as each casting. To see whether the test-piece gave a reliable indication of the strength of the whole casting, 11 castings were chosen at random, and they and their associated test-pieces were broken. The breaking stresses (tons/sq. in.) were as follows:—

Casting (y)	45	67	61	77	71	51	45	58	48	62	36
Test-piece (x)	39	86	97	102	74	53	62	69	80	53	48

Estimate the regression equation and draw the line and the observed points on a graph. The test-piece of a further casting had a breaking stress of 35 tons/sq. in. What is the minimum strength of the casting likely to be ?

6. Explain the use of the table of the standardized normal probability integral, $\Phi(x)$, to find the expected proportion of observations lying between a and b in a normal distribution of mean μ and standard deviation σ. Distinguish between the cases $\mu < a < b$ and $a < \mu < b$.

Show that if two independent random variables x and y have the same means μ and the same variances σ^2, then (a) the means of $x+y$ and $x-y$ are 2μ and zero respectively, (b) the variances of $x+y$ and $x-y$ are both $2\sigma^2$, (c) $x+y$ and $x-y$ are independent.

Two resistors are each to be constructed by connecting in series 10 coils of wire chosen at random from a large collection of coils in which the resistance is normally distributed with a standard deviation of 0·1 ohm. Find the probability that the completed resistors differ by more than 1 ohm.

7. In the mixing of an explosive powder, four mixers were used. The powder was charged into cartridge primers by four operators, A, B, C and D. The experiment was carried out in four days and was designed as a 4×4 Latin square. Explosive forces were measured, the results being as follows:—

	Mixer			
	1	2	3	4
Monday	46(B)	51(A)	70(D)	52(C)
Tuesday	71(D)	49(C)	42(B)	50(A)
Wednesday	57(A)	62(D)	56(C)	47(B)
Thursday	48(C)	41(B)	54(A)	69(D)

Carry out an analysis of variance to study differences between mixers, chargers and days. If any of these effects is significant, calculate the appropriate means and their standard errors.

8. The distribution of a random variable x has mean μ and variance σ^2. Show that to a first order of approximation the mean and variance of $\log_e x$ are $\log_e \mu$ and σ^2/μ^2, respectively.

Solid right circular metal cones of height h and radius r are accepted on testing after manufacture provided their volumes do not exceed 20 cu. in. The dimensions h and r are distributed independently with the same standard deviation σ about the respective mean values 2 in. and 3 in. Find the greatest tolerable value of σ if the frequency of rejection is not to exceed 1% assuming that the logarithm of the volume is normally distributed ($\log_e 10 = 2{\cdot}3026$).

9. Describe the use of χ^2 for testing the agreement of a set of observed frequencies with those expected according to some hypothesis. Give a general rule for determining the degrees of freedom associated with the χ^2. Why is the significance test only approximate ?

Two fuses are included in the same apparatus and are assumed to have independent probabilities p and p' of being blown in a certain experiment. Show that the probabilities of both being blown, one only, or neither during the experiment are given by pp', $p+p'-2pp'$ and $1-p-p'+pp'$ respectively.

If it is known that $p = 0{\cdot}3$ and $p' = 0{\cdot}1$, test the hypothesis that the actions of the fuses are independent given that with 200 repetitions of the experiment one fuse was blown on 58 occasions and both were blown on 12 occasions. Comment briefly on the result of the significance test.

September 1961

MATHEMATICS I

OLD REGULATIONS

Examiner: A. W. GILLIES, B.Sc., PH.D., F.INST.P.

WEDNESDAY, 7th June—9.30 a.m. to 12.30 p.m.

(*Answer* SIX *questions*)

1. (*a*) Obtain the roots of the equation

$$\begin{vmatrix} 1-\lambda & 2 & 3 \\ 2 & 3-\lambda & 1 \\ 3 & 1 & 2-\lambda \end{vmatrix} = 0$$

(*b*) Obtain the equation of the circle through the points (4, 0), (0, 2) and (−2, −2). What is the radius and what are the co-ordinates of the centre of this circle ?

2. (*a*) Obtain the general solution of the equation

$$\frac{dy}{dx} = \frac{x^3 - 3xy^2}{y^3 - 3x^2y}$$

(*b*) Obtain the solution of the equation

$$\frac{d^2y}{dx^2} + 2\frac{dy}{dx} + 2y = 5\cos x$$

which satisfies the initial conditions $y = 1$ and $\frac{dy}{dx} = 0$ at $t = 0$.

3. Sketch the curve represented by the equation

$$ay^2 = x(a-x)^2$$

Determine the area enclosed by its loop and the volume of the solid of revolution generated by rotating this loop about the x-axis.

4. Two complex numbers $Z = x + iy$ and $W = u + iv$, where x, y, u, v are real, are connected by the equation $W = Z + 1/Z$, thereby establishing a correspondence between points P(x, y) and Q(u, v). The point Q describes the closed path formed by the segment AB of the u axis between $u = 1$ and $u = 2$; the arc BC, with centre at the origin and radius 2, from the u-axis to the v-axis; the segment CD of the v-axis from $v = 2$ to $v = 1$, and the arc DA with centre at the origin and radius 1. Determine the path described by the corresponding point P.

5. The variables x and y are functions of t satisfying the simultaneous differential equations

$$\frac{dx}{dt} = 2 + x + y$$

$$\frac{dy}{dt} = 6 - 5x - 3y,$$

together with the initial conditions $x = 1$, $y = 0$ at $t = 0$. Obtain x and y explicitly as functions of t and sketch their graphs.

6. If $y = e^x \cos 2x$, obtain $\frac{dy}{dx}$ and show that

$$\frac{d^n y}{dx^n} = 5^{n/2} e^{-x} \cos(2x - n\alpha),$$

where $\alpha = \tan^{-1} \frac{1}{2}$.

Hence, or otherwise, obtain the expansion of y as a series in ascending powers of x. For what values of x is this expansion valid ?

7. The position vector of a point P is $\mathbf{r}$. Show that P will lie on a particular plane if

$$\mathbf{r} = \mathbf{a} + \lambda\mathbf{b} + \mu\mathbf{c}$$

where $\mathbf{a}$, $\mathbf{b}$ and $\mathbf{c}$ are fixed vectors and λ, μ are variable scalar parameters.

Show that P will also lie on a plane if

$$\mathbf{r} . \hat{\mathbf{n}} = p$$

where $\hat{\mathbf{n}}$ is a fixed unit vector and p a fixed scalar. If these equations represent the same plane, express $\hat{\mathbf{n}}$ in terms of $\mathbf{a}$, $\mathbf{b}$ and $\mathbf{c}$ and show that

$$p = \frac{[\mathbf{a}\ \mathbf{b}\ \mathbf{c}]}{|\mathbf{b} \times \mathbf{c}|}$$

8. A particle P moves under an attractive force toward a fixed centre O, of magnitude μ/r^2 per unit mass, where $r = \mathrm{OP}$.

If the particle is projected with speed V_o from a point at radius r_o show that the orbit will be an ellipse if $V_o^2 < 2\mu/r_o$, the semi-major axis being given by the equation

$$\frac{\mu}{2a} = \frac{\mu}{r_o} - \frac{1}{2} V_o^2.$$

9. A set of numbers is denoted by x_r, $(r = 1, 2, \ldots, n)$. If $\sum_{r=1}^{n} x_r = nm_1$, and $\sum_{r=1}^{n} x_r^2 = nm_2$, discuss the information about the set of numbers which is provided by a knowledge only of m_1 and m_2.

10. A uniform rod AB of length $2l$ and mass m stands vertically with the end A resting on a rough horizontal table. It is very slightly displaced so that it falls over, rotating in a vertical plane about the end A. Assuming A does not slip, determine the angular speed of the rod when it has turned through an angle θ, and also the horizontal and vertical components of the reaction at A. Discuss whether the end A is likely to slip at any point in the motion.

September 1961

MATHEMATICS II

OLD REGULATIONS

Examiner: A. W. GILLIES, B.Sc., PH.D., F.INST.P.

WEDNESDAY, 7th June—2.00 p.m. to 5.00 p.m.

(*Answer* SIX *questions*)

1. (i) Assuming that when x is small, the equation

$$y^3 - 2y^2 + xy + 2x = 0$$

has a root for y near to $y = 2$, which may be expanded in powers of x in the form

$$y = 2 + bx + cx^2 + \ldots$$

show that $b = -1$ and determine c.

(ii) By using the series for $\sinh x$ and $\cosh x$, or otherwise, obtain the expansion for $\tanh x$ in ascending powers of x as far as the term containing x^5.

2. (i) Show that $\int_0^1 \frac{dx}{(x+1)^2(x+2)} = 1/2 - \log(4/3.)$

(ii) Show that $\iint x^2y^2dxdy$, taken over the first quadrant of the circle with centre at the origin and radius a, has the value $\pi a^6/96$.

3. If $I_n = \int \frac{dx}{(x^2+a^2)^n}$ for any value of n, show that

$$2na^2I_{n+1} = (2n-1)I_n + \frac{x}{(x^2+a^2)^n}$$

provided the constants of integration are properly chosen.

Evaluate $\int_0^\infty \frac{dx}{(x^2+a^2)^2}$ and $\int_0^\infty \frac{dx}{(x^2+a^2)^{3/2}}$.

4. The rate of flow of a gas through an orifice may be assumed to depend on the orifice diameter d, the kinematic viscosity ν and density ρ of the gas, and the pressure difference p across the orifice.

Use the method of dimensional analysis to show that the volume Q of gas flowing per unit time is given by

$$Q = d^2\sqrt{\frac{p}{\rho}}f\left(\frac{\nu^2\rho}{d^2p}\right)$$

where f denotes an undetermined function.

5. If x is a function of t defined by

$$x = \int_0^t \frac{\sin \omega(t-\tau)}{\omega} f(\tau)\,d\tau$$

where $f(\tau)$ denotes a function of τ, obtain dx/dt and show that

$$\frac{d^2x}{dt^2} = f(t) - \int_0^t \omega \sin \omega(t-\tau) f(\tau)\,d\tau.$$

Use this result to obtain the solution of the equation

$$\frac{d^2x}{dt^2} + \omega^2 x = \cos \omega t$$

which satisfies the initial conditions $x = 0$, $\dfrac{dx}{dt} = 0$ when $t = 0$.

6. The function $f(t)$ of period T rises exponentially from a at $t = 0$ to b at $t = T$ when it returns instantaneously to the former value. Show that $f(t) = ae^{ct}$ for $0 < t < T$, where $c = (1/T) \log (b/a)$.

Sketch the graph of $f(t)$ against t for three cycles beginning at $t = -T$. Determine the ratio of the amplitude of the second harmonic to that of the fundamental, and also the ratio of the latter to the constant term of the Fourier expansion of $f(t)$.

7. By expressing in polar co-ordinates, or otherwise, determine the lengths of the principal semi-axes, and the inclination to the x-axis of the major axis of the ellipse represented by the equation

$$52x^2 + 72xy + 73y^2 = 100.$$

8. Show that the equation

$$r^2 \frac{\partial^2 V}{\partial r^2} + r \frac{\partial V}{\partial r} + \frac{\partial^2 V}{\partial \theta^2} = 0$$

has solutions of the form $f(r)e^{ni\theta}$ and determine the form of $f(r)$.

Obtain a solution of this equation which vanishes on the circle $r = a$, and reduces to $\sqrt{2} \cos(\theta - \pi/4)$ on the circle $r = b$, when r and θ are plane polar co-ordinates.

9. A circle rolls without slipping along the x-axis. At any instant the centre is at C, the point of contact is A, and B is the opposite extremity of the diameter through A.

If P is any point of the circumference, show that the velocity of P is of magnitude $\omega \cdot PA$ along the line PB, while the acceleration is the resultant of two components the first of magnitude $\alpha \cdot PA$ along the line PB, the second $\omega^2 \overrightarrow{PC}$. ω and α denote the angular speed and acceleration of the circle.

10. Six uniform rods, each of length a and weight W are freely jointed together to form a hexagon ABCDEFA. The system is suspended from A, and is prevented from collapsing by an elastic string joining AD. The string has a natural length $4a/3$ and would be extended to twice this length if it were to support the whole weight of the hexagon. Determine the angle between AB and the string, the tension in the string, and the reaction between the rods meeting at C, when the system is in equilibrium.

September 1961

PRACTICAL PHYSICS

OLD REGULATIONS

Examiners: K. J. CLOSE, B.Sc., A.INST.P., and J. YARWOOD, M.Sc., F.INST.P.

FRIDAY, 2nd June

(All day, beginning at 9.30 a.m.)

(Six hours allowed)

(TWO *questions, selected by the Examiners, will be allotted to each candidate*)

1. Find the velocity of propagation of longitudinal sound waves in the steel rod provided.

2. Determine the electrostatic deflection sensitivity of the given cathode ray tube and explore how this sensitivity depends upon the final anode voltage.

3. Determine the specific charge on the electron by means of a gas-focused electron tube.

4. Obtain a speed against pressure characteristic for the given mechanical rotary pump.

5. Find the manner in which the longitudinal spherical aberration of the thick lens varies with its aperture.

6. Determine the wavelength of light from the monochromatic source supplied by means of the apparatus provided.

7. Determine the viscosity of air.

8. Find the fundamental interval of the platinum resistance thermometer.

9. For the Hall probe supplied determine the Hall e.m.f. for currents up to 90 mA max with the plane of the probe set up perpendicular to the uniform magnetic field within the gap of an electromagnet.

10. Determine the latent heat of vaporization of liquid oxygen.

11. Measure the dielectric constant of the liquid provided by means of a high-frequency resonance method.

12. Investigate the absorption in iron of the γ-rays from a cobalt-60 source.

13. Find the current and charge sensitivity of the ballistic galvanometer.

14. Use the components provided to construct an audio-frequency amplifier. Measure the gain at frequencies of 50, 1,000 and 10,000 cycles per sec. Compare the measured gain with the calculated value.

GENERAL PAPER

OLD AND NEW REGULATIONS

Examiner: N. CLARKE, B.Sc., F.INST.P.

TUESDAY, 6th June—9.30 a.m. to 12.30 p.m.

(*Answer any* FIVE *questions*)

1. Discuss the proposal that the Government should subsidize sport in Britain.

2. If you were Minister of Transport, how would you attempt to deal with traffic congestion and problems of road safety ?

3. Discuss the ways in which the invention of the internal combustion engine has affected the lives of people in Britain.

4. What is your opinion of modern painting and sculpture ? Quote examples to illustrate your answer.

5. Discuss the problems facing the Government in securing men for the armed forces. How would you solve some of the problems ?

6. What do you understand by *communism, fascism, capitalism, liberalism, socialism, monopoly* ?

7. If you had the opportunity to do so, which four people would you select for inclusion in the next honours list ? Why ? What award would you give to each ?

8. What improvements would you like your local Council to make in the town in which you live ? Include in your answer an estimate of the cost.

9. Discuss the issues raised by the closure of the *News Chronicle* and the sale of the *Daily Herald*.

10. What do you think of " Angry Young Men " ?

PHYSICS I

NEW REGULATIONS—PART I

Examiner: A. E. DE BARR, B.Sc., F.INST.P.

WEDNESDAY, 7th June—9.30 a.m to 12.30 p.m.

(*Answer* FIVE *questions*)

1. A mass, restrained by a linear spring, is constrained to move in a straight line and is subject to a resisting force proportional to the speed. Discuss the response of the system to periodic driving forces of different frequencies.

Comment on the design of

(*a*) An anti-vibration mounting for a sensitive galvanometer

(*b*) A case in which the galvanometer can be packed for transport by railway.

2. Write an essay on " The timing of a pendulum ".

3. A metal block rests on a rough horizontal surface. A string extends horizontally from the block, passes round a pulley and supports a scale pan hanging freely. Explain how the frictional force on the block varies as weights are added to the scale pan.

Discuss the physical phenomena responsible for the behaviour you have described and comment on the effect of the addition of a lubricant between the block and the plane.

4. Use a simple kinetic theory to obtain an expression for the thermal conductivity of a gas, and indicate the way in which this quantity varies with temperature and pressure. Why, and in what way, does the behaviour of actual gases differ from that predicted by this expression ?

Make an estimate of the ratio of the thermal conductivities at N.T.P. of argon (Atomic Mass 40) and nitrogen (Molecular Mass 28), given that the mean free paths at N.T.P. are $6{\cdot}3 \times 10^{-6}$ cm and $5{\cdot}8 \times 10^{-6}$ cm respectively.

5. Define (i) surface tension, (ii) surface energy. Explain in general terms why a soap film cools when it is stretched.

Describe a convenient method for the investigation of the variation of surface tension with temperature.

6. The radius of curvature of the path of a charged particle in a magnetic field is dependent upon (*a*) the charge on the particle, (*b*) the mass of the particle, (*c*) the velocity of the particle and (*d*) the magnetic flux density. Use the method of dimensions to obtain an expression for the radius of curvature of the path of the particle in terms of these four quantities.

Explain how use is made, in the design of experiments on models of full-scale equipment, of a knowledge of the dimensions of physical quantities.

7. Show from first principles that the value of Poisson's ratio for an isotropic solid cannot exceed 0·5.

Describe two methods of measuring Poisson's ratio. In what circumstances would you expect a direct measurement of this quantity to give a result differing from that calculated from the values of Young's modulus and the modulus of rigidity ?

8. Explain the production of beats and combination tones in the human ear, and discuss the conditions necessary for their detection.

Why are combination tones of importance when listening to music relayed by a small, unbaffled loudspeaker ?

9. Explain what is meant by " acoustical impedance " and discuss the importance of this quantity in relation to the transmission of acoustic waves in inhomogeneous media. Give examples.

Calculate the acoustical impedance per unit area of the wave front given that the velocity of sound in air is $3{\cdot}4 \times 10^4$ cm sec^{-1} and that the bulk modulus of elasticity of air is $1{\cdot}4 \times 10^6$ dyne cm^{-2}.

PHYSICS II

NEW REGULATIONS—PART I

Examiner: PROFESSOR G. K. T. CONN, M.A., PH.D., F.INST.P.

WEDNESDAY, 7th June—2.00 p.m. to 5.00 p.m.

(*Answer* FIVE *questions, at least* TWO *from each section*)

SECTION A

1. Discuss the measurement of temperature and, by considering in particular how you would measure temperatures greater than about 2500°C, explain the problems of establishing a temperature scale.

2. What is the evidence that heat is a form of energy ?

Describe a good method of measuring the mechanical equivalent of heat. Why is it that the mechanical equivalent is commonly measured by converting work into heat rather than by converting heat into work ?

3. By comparing the thermal behaviour of real gases with the predictions of the van der Waals equation of state, examine the distinctions between real and perfect gases. Comment on the adequacy of the van der Waals equation.

4. Show that in a reversible cycle, plotted on a pressure-volume diagram, the area enclosed by the cycle represents the work done. By discussing the features of a Carnot cycle, explain what is meant by thermodynamic efficiency.

In an ice rink, 100 lbs. of ice will melt per hour if the outside temperature is 17°C. What is the least horse-power required to prevent this loss ?

(1 horse power is equivalent to 33,000 ft-lb per minute; the Mechanical Equivalent of Heat is 1400 ft-lb per lb-°C; Latent heat of fusion, 80 lb°C per lb.)

5. Write an essay on the thermal insulation of houses.

SECTION B

6. A Ramsden eyepiece consists of two thin converging lenses each of focal length 3 cm, separated by a distance of 2 cm. Determine the positions of the cardinal points of the system. The cardinal points should be defined and their position, for the eyepiece, shown on a diagram.

Comment on the aberrations of the instrument.

7. The variation of the refractive index of quartz with wavelength is given in the following table:

λ in Å	2749	2914	3034	3123
Refractive index	1·5875	1·5810	1·5770	1·5733

Derive an expression for the resolving power of a prism. Calculate suitable dimensions for a quartz prism to have a resolution, in the neighbourhood of 3000 Å, as good as that of a grating of 5000 lines per cm and 3 cm wide. Make a drawing, giving reasonable dimensions, of such a prism spectroscope.

8. Describe carefully any form of interferometer suitable for measuring the refractive index of a gas.

Comment on applications of interferometry in industry.

9. How has the velocity of light been measured with precision ? Why is great importance attached to this constant ?

September 1961

PHYSICS III

NEW REGULATIONS—PART I

Examiner: PROFESSOR J. D. CRAGGS, M.Sc., PH.D., F.INST.P.

THURSDAY, 8th June—2.00 p.m. to 5.00 p.m.

(*Answer* FIVE *questions*)

1. Derive an expression for the charge sensitivity of a ballistic moving-coil galvanometer with negligible damping. Assuming that the instrument has a periodic time of 5 secs. and a sensitivity of 150 mm/micro-coulomb, determine its d.c. sensitivity (mm/micro-ampère).

2. How would you measure (i) an inductance of about 1 Henry, (ii) a d.c. potential of 1 million volts, and (iii) the absolute value of the ampère ?

3. Describe, with appropriate theory, an alternating current bridge method for measuring capacitance. How would you choose components to give the greatest sensitivity ?

4. How may the positions of equipotential surfaces be determined in an axially symmetrical electrostatic two cylinder electron optical lens ? The absence of space charge is to be assumed. How would you determine the trajectories of electrons in such a system and what further information would be required ?

5. Show how the current varies with time in a circuit containing L, C and R after the application of a constant e.m.f. giving particular attention to variations in damping. All definitions should be clearly given. How would you confirm the results of the above calculations by experiment ?

6. Describe a modern form of mass spectrometer. Discuss some of the results obtained with it.

7. Derive formulae for the rate of decay of a radioactive element, separated from the parent element, and for the apparent rate of recovery of the parent's activity. Give an example of such a case. How may radioactivity determinations of the age of minerals be made ?

8. Give the theory of the cyclotron and outline the subsequent development of particle accelerators.

MATHEMATICS

NEW REGULATIONS—PART I

Examiner: G. A. P. WYLLIE, B.Sc., PH.D., F.INST.P.

THURSDAY, 8th June—9.30 a.m. to 12.30 p.m.

(*Answer questions 1, 2, 3, and as many others as you can*)

1. (*a*) Find the turning points, and the curvature at the turning points, of the curve

$$y = ax^2(x^2 - b^2).$$

Sketch the curve.

(*b*) $y = ax^{-n} - bx^{-m}$, $a > 0$, $b > 0$, $n > m > 0$.

Where is the minimum of y, and what is the second derivative at the minimum ?

(*c*) Evaluate $\int_0^\infty x^n e^{-\lambda x}\,dx$, n a positive integer,

$\int_0^{\pi/2} \sin^m\theta \cos^n\theta\,d\theta$, m, n positive integers.

2. (*a*) Find the centroid of a uniform solid hemispherical shell of internal radius a and external radius $2a$.

(*b*) Show that $\cos n\theta$ is a polynomial of degree n in $\cos\theta$. Find the roots θ_r of $\cos n\theta = 0$ for $0 \leqslant \theta_r < 2\pi$, and show that $\cos n\theta = \prod_r (\cos\theta - \cos\theta_r)$.

(*c*) Solve the equation $\ddot{x} + 2k\dot{x} + \omega^2 x = 0$ and show that for $k > \omega$, x can have no more than one zero for $0 \leqslant t < \infty$. Given initial conditions $x = a$, $\dot{x} = u$ at $t = 0$, what relationship must exist between u and a for x to change sign for a finite value of t?

3. (*a*) Show that $\partial y/\partial x = -c^{-1}\,\partial y/\partial t$ represents a wave of constant shape travelling in the direction of increasing $x (c > 0)$.

(*b*) $y = \sin^3(\pi x/l)$, $0 \leqslant x \leqslant l$. Express y as a Fourier sine series in this interval.

(*c*) Find the smallest positive root of $3x = \tan x$, to three significant figures.

4. Prove that a determinant with two identical rows or columns is zero, and hence that the value of a determinant is unchanged by adding any multiples of one row (or column) to the other rows (or columns). Hence or otherwise express

$$\begin{vmatrix} x^2 & yz & 1 \\ y^2 & zx & 1 \\ z^2 & xy & 1 \end{vmatrix}$$

as a product of linear factors and find its quotient by

$$\begin{vmatrix} x^2 & x & 1 \\ y^2 & y & 1 \\ z^2 & z & 1 \end{vmatrix}$$

5. (*a*) If $F(x, y, z) = 0$, is implicitly a function of x and y, prove that $\dfrac{\partial z}{\partial x} = -\dfrac{\partial F}{\partial x}\Big/\dfrac{\partial F}{\partial z}$

and hence or otherwise show that the tangent plane to the surface

$$2z^3 + 3(x + y)z^2 = 1$$

at any point is equally inclined to the x and y axes.

(*b*) Express $\left[\int_0^\infty x^2 \exp(-x^2)\,dx\right]^2$ as a double integral, transform to plane polar co-ordinates and evaluate.

6. A uniform circular disc is suspended from a fixed point by a light cord of length equal to the radius a of the disc, attached to a point on the circumference. Find the frequencies of oscillation of the system for motions parallel to a vertical plane

(*a*) normal to the plane of the disc.

(*b*) in the plane of the disc.

7. Show that if an event has probability x on a single trial, the probability of this event arising m times out of n trials is

$$P(m, n) = \frac{n!}{m!(n-m)!}\, x^m (1-x)^{n-m}$$

Prove that if now $n \to \infty$ and $x \to 0$ so that $nx \to \theta > 0$,

$$P(m) = \lim_{n\to\infty} P(m, n) = \frac{\theta^m}{m!}\, e^{-\theta}$$

Suppose that an ideal gas of N molecules occupies a volume nV, where N and n are both large. Show that the mean squared deviation of the number of molecules in a specified volume V is N/n.

Manuscripts accepted for publication in the Institute and Society's periodicals

British Journal of Applied Physics

Investigation of a method of growing crystals of GaP and GaAs from the vapour phase. By G. R. Antell.
Crystals of GaP and GaAs were grown from the vapour at about 900°c using an iodide process. The crystals were deposited on a localized cold spot and their initial growth could be readily observed. Single crystal samples of GaP had resistivities of the order of 5×10^8 ohm cm. The concentration of iodine in the GaP crystals was found to be less than 2 parts in 10^6. A p-type sample of GaAs was grown at less than 800°c which had a Hall coefficient of 53 cm^3 $coulomb^{-1}$.

Method of measuring the growth of a control specimen of graphite after irradiation. By P. A. E. Crose and W. L. Snowsill.
A method is described for measuring the length of control specimens of graphite accurately without placing any reliance on the condition of the end faces, or any surfaces of the graphite.
A specially shaped groove is turned near each end of the 10 cm long × 1·25 cm diameter specimen, and is filled with flame sprayed Magnox. A technique is described for producing a high-quality surface on the Magnox on which a diamond indentation under microscopic examination appears as a pair of cross wires.
Using the 'cross wires' as datum marks, and a high-quality travelling microscope, measurements to an accuracy of 1 in 25000 are readily attainable. Methods are discussed for increasing this to a possible 1 : 100000.

On the transfer relation of a manometer for liquid level measurements. By S. Dutta Roy.
The relation between the motion of a mercury surface in a manometer for liquid level measurements, and that of the liquid to which it is connected, has been deduced and methods have been worked out for making this relation perfectly linear.

High power heating of a cylindrical tube by electron bombardment of the inside surface. By R. E. Haigh and P. H. Dawson.
When it is necessary for the high heat rating of power reactor fuel elements to be simulated in 'out of pile' tests, the heating of the test element can be a major problem. The method of heating chosen for a particular rig will depend on the exact nature of the tests for which the rig is designed, and the requirements of the tests may make conventional heaters unsuitable. Very high heat fluxes can be obtained by electron bombardment and this method has been used to simulate reactor heat ratings in rig tests on a Calder Hall type element. The test element was essentially a co-axial diode; a vacuum tube representing the fuel rod was the anode, the cathode being a tungsten wire stretched down the centre. Maximum reactor heat ratings were achieved easily and it is considered that if required the power input could have been several times greater. This paper discusses the characteristics of the method and describes the important features of the design.

This paper was presented at the Symposium on the Design of Experimental Equipment for Use in Nuclear Energy Research—11th–14th April, 1961, held at the Atomic Energy Research Establishment, Harwell.

INVITED ARTICLE

Electroluminescent devices. by H. K. Henisch.
A survey is made of recent progress in the applications of electroluminescence, dealing with panels for illumination purposes, with alphanumerical indicators, with light and picture amplifiers of various kinds, as well as scanned picture displays.

INVITED ARTICLE

Changing instrumentation of high energy physics. By G. W. Hutchinson.
The possibility is reviewed of using hodoscopes, spark chambers and Čerenkov devices in combination for investigating complicated and unusual reactions of elementary particles at high energies.

CONFERENCE REPORT

Conference on electron microscopy—Nottingham, July 1961. By P. M. Kelly and R. Read.
The annual conference of the Electron Microscopy Group of The Institute of Physics and The Physical Society was held in the Department of Chemistry, The University of Nottingham, from 10th–14th July, 1961. A general account of the proceedings is given.

Vacuum deposited metal film resistors. By G. Siddall and B. A. Probyn.
Although vacuum-deposited thin metal films have been studied for many years, it is only recently that their anomalous electrical properties have been turned to practical account. In this work the most important requirements for the deposition of metal film resistors are discussed, and an annealing cycle up to 300–350°c in air is proposed to stabilize the resistance of nickel–chromium alloy films, preventing further large irreversible change within the temperature range of normal use. The stability of annealed unprotected films within the range 10–400 ohms/square was determined over a period of 2000 hours on load (1 w/in^2) and 8000 hours at no load. Frequency diagrams show the number of resistors measured, and their percentage resistance change. Resistors at no load increased by an average of 1%, compared with a very small mean decrease in the same resistors on load. The temperature coefficient of resistance of films in the range 100–150 ohms/square is shown to vary between 0·002 and 0·1% per deg c and is related to the rate of film deposition. Starting with an alloy of 80/20 nickel–chromium, the lowest values of temperature coefficient of resistance are obtained for rates of deposition lower than 5 Å/s, and this effect is discussed in terms of the oxidation of the film and the separation of the alloy during evaporation.

Journal of Scientific Instruments

Dekatron scaler, employing transistorized drive circuits. By G. Bradford and R. B. Galloway.
A scaling circuit is described which has proved extremely reliable, consisting of two dekatron stages followed by a mechanical register. The resolving time of the circuit is 250 μs.

Self-contained integrating irradiance meter for use underwater. By L. Draper.
A self-contained instrument is described which will record the total light energy, within known spectral limits, received at a point during a period of time such as one day. It has a linear response to light intensity and makes its record in digital form. It was designed to be used at sea. The integrator is electronic, not mechanical, so that it is not affected by the accelerations to which bodies floating near the surface of the sea are subjected.

Robust helical spring microbalance. By D. Griffiths.
An account is given of the construction of a simple null-reading balance which has been used for low temperature magnetic susceptibility measurements and may have wider applications. Supporting a 40 g load, this slim helical spiral spring device has a noise level of less than two micrograms under normal laboratory conditions, achieved as the result of a mechanical filtering action. The apparatus is robust, inexpensive, and easily constructed.

Radial shearing interferometer. By P. Hariharan and D. Sen.
A new type of wave front shearing interferometer is described in which two images of the wave front under test which are of different sizes are made to interfere. When the centres of the two images coincide, this results effectively in shear along the radial direction. It is shown that the interpretation of the resulting interferogram is comparatively easy. In addition, the instrument is extremely convenient to handle, since all the adjustments can be made with a white light source.

Analogue computer for the summation of Fourier series with digital recording of the results. By T. Lundström and V. Klimecki.
An a.c. analogue computing machine is described, which carries out the summation of the Fourier Series

$$\sum_{h=0}^{H} A_h \cos 2\pi hx + \sum_{h=0}^{H} B_h \sin 2\pi hx$$

with $H_{max} = 40$ for every third degree. The calculation is performed by a method in principle given by Hägg and Laurent. Voltages from an autotransformer, proportional to the trigonometric functions, are connected to decade potentiometers, introducing the coefficients via rotary switches. From these potentiometers small currents are fed to a common impedance, and the voltage over this gives the sum of the Fourier series. The result is converted to digital form by means of a relay system and printed automatically. The time necessary for one summation is 3 seconds. An example showing the accuracy is given.

Improved field discriminator for magnetic field stabilization. By K. H. Marsden.
The automatic frequency control of a nuclear magnetic resonance field discriminator oscillator using an external crystal reference and a germanium diode as a high Q voltage dependent capacitor, is described. A frequency stability of 1 part in 10^7 is achieved, while allowing the frequency to be scanned through a range of 30 kc/s about the centre frequency of 30 Mc/s. The discriminator unit provides fine control of the 7000 gauss field of a large electromagnet and produces a corresponding 0·1% field scan with a stability better than 1 part in 10^6.

Height of waves in hydraulic models by the method of stereoscopy. By J. W. Railly.
The analogy between the flow of shallow water over a horizontal plane and the two-dimensional unsteady flow of a compressible gas is well known, and

an interpretation of the behaviour of the hydraulic model, and hence of the gas, requires, at any instant of time, the distribution of water depth over a horizontal plane. Because the flow may often be of a time-dependent type, a photographic method has obvious advantages, and the only one which appears suitable is the method of stereoscopy. In this application three lenses are used, and the glass table over which the water flows is lit from below by well-diffused light from electronic flash. The water surface is marked by the use of floating markers obtained by the introduction of teleprinter 'confetti', a bye-product of the punching of paper tape. The optimization of the optical system and the method of obtaining the height of any of the floating markers, and hence of the water surface, is described; with a moderate outlay water depths can be measured to 0·005 in.

Instrument for cutting animal tissues into small pieces (3 mm³) with preservation of viable cells. By A. L. Sims.
This instrument is designed to cut animal tissue into minute pieces (about 3 mm³) with the minimum of crushing of cells. Cutting is by a continuous scissors-like shearing action and the instrument is self-sharpening. A steel disk with a spiral groove cut in one face is rotated horizontally below a vertical rectangular steel plate. Cutting takes place when tissue in a specially shaped container is pressed by a sliding weight into the groove of the spiral and upon rotation is carried against the sharp toothed edge of the stationary rectangular vertical steel plate. The cut pieces in the spiral groove are removed by a gear wheel in continuous mesh; they then fall into a catch tray.
The size of the pieces cut is governed by three factors: (i) the width and depth of the spiral groove, (ii) the weight pressure and (iii) the spacing of the buttress—shaped teeth along the cutting plate edge.

Improved microfurnace power supply. By J. H. Welch.
A previously described hot-stage device for high-temperature microscopy, in which specimens are supported by a thermocouple used both for heating and temperature measurement, uses a high-speed switch to interrupt the heating current at intervals during which temperataure measurement takes place. Interruption of the heating current by silicon rectifiers minimizes maintenance problems and inaccuracies of temperature measurement which may arise with mechanical switching. Precautions for avoiding other sources of inaccuracy in temperature measurement are also described.

Crystal-pulling furnace for gallium arsenide. By R. Wickham.
The design and operation of equipment for pulling single crystals of gallium arsenide are described. Features of the design include a demountable quartz system with rapidity of set up and ease of operation, close control of the arsenic pressure in the tube, and very good vision during the crystal growing cycle. The heating element is of resistance heated graphite and is traversable.

X-ray diffractometer for automatic operation. By W. A. Wooster and A. M. Wooster.
A description is given of an x-ray diffractometer designed for automatic operation using punched tape input information. Four circles are normally used. Two large 360-tooth circles having their axes vertical and collinear are used to set the detector and the plane of the vertical circle respectively. The third circle provides a rotation about a horizontal axis of the fourth circle on which the goniometer head is mounted. The gear mechanism for ensuring the independence of the last two settings is described. The merits of a complete vertical circle as compared with quarter, half and three-quarter circles are discussed and it is shown that the mechanical advantages of a complete circle generally outweigh the disadvantages due to obstruction of the x-ray beam, which are, anyway, much less than commonly supposed.

Proceedings of The Physical Society

Zero-field paramagnetic resonance of Fe^{3+} in methylamine alum. By G. S. Bogle and H. F. Symmons.
The splitting of the ground level of Fe^{3+} in $(CH_3NH_3)Al(SO_4)_3 \cdot 12\,H_2O$ in the absence of a magnetic field has been measured directly. At 90°K the separation of the $Sz = \pm 3/2$ states from the $\pm 1/2$ is equivalent to 12 227 ± 5 Mc/s, and that of the $\pm 5/2$ from the $\pm 3/2$ to 22 043 ± 10 Mc/s. The deduced values of the coefficients in the usual spin-Hamiltonian for the ferric alums are $D = +0{\cdot}1893 \pm 0{\cdot}0002$ and $a - F = +0{\cdot}0171 \pm 0{\cdot}0001$ cm^{-1}, and it is probable that $a \geq +0{\cdot}013$, $F \geq -0{\cdot}004$ cm^{-1}. The material is promising for a zero-field maser, with predicted amplifying and pumping frequencies of 12 230 ± 15 and 34 460 ± 45 Mc/s respectively at liquid-helium temperatures.

Post-arc temperature decay. By Dr. J. W. S. Allan, Dr. H. Edels and Dr. D. Whittaker.
A method is described for determining the inter-electrode gas temperature at any chosen time following the current interruption of an arc discharge, using a rotating mirror camera to measure the velocity of a shock wave passing through the gas. From a series of such measurements the rate of temperature decay may be found, and results are given for times between 100 μsec and 1 sec after interrupting arcs in air between carbon electrodes. The average rates of decay of the mean core temperature during 1 msec following current interruption were 1·5 deg μsec^{-1} for an 8 mm gap (10 or 40 A) and 2·8 deg μsec^{-1} for a 2 mm gap (40A). The temperature decay subsequent to a 40A arc has also been calculated from a knowledge of the gas properties and with the assumptions of cylindrical symmetry and energy loss by thermal conduction only.

The elastic scattering of positrons by atomic hydrogen and helium. By D. C. S. Allison, H. A. S. McIntyre and B. L. Moiseiwitsch.
The variational methods of Kohn and Hulthén are employed to calculate the scattering lengths for elastic collisions between positrons and hydrogen and helium atoms. Allowance is made for the dipole polarizability of the target atom by using a trial function which includes a term corresponding to the first-order perturbation of the atom due to the electric field of the positron.
The effect of allowing for the dipole polarizability of the atom is to change the sign of the scattering lengths for both hydrogen and helium in agreement with the variational calculations made by Spruch and Rosenberg in 1960 for hydrogen. In the case of hydrogen the total elastic cross section at zero impact energy is increased when allowance is made for polarization but in the case of helium it is decreased from $0{\cdot}72\pi\ a_0^2$ to $0{\cdot}10\pi\ a_0^2$. The experimental cross section derived by Teutsch and Hughes in 1956 for 18 ev positrons in helium is still smaller, being only $0{\cdot}023 \pm 0{\cdot}006\pi a_0^2$.

Electron spin resonance in two groups of lanthanon salts. By R. S. Rubins and J. M. Baker.
Electron spin resonance measurements have been made on lanthanon ions in the hexa-antipyrene iodide (HAPI) salts and also in lanthanum trifluoride. At room temperature the HAPI have trigonal symmetry with one lanthanon ion per unit cell but at low temperatures there is a change of crystal structure. For all ions except Ce^{3+} and Gd^{3+} electron spin resonance is observed only at temperatures below the transition. The lanthanon ion in the HAPI at low temperatures and in the trifluoride have rhombohedral point symmetry and there are several ions in the unit cell. Not all ions with Kramers degeneracy exhibited resonance in both salts, and the few non-Kramers cases investigated also exhibited no resonance. In both salts the most extensive measurements were made on Ce^{3+}. In the HAPI Ce^{3+} has a remarkably long relaxation time and the spectrum is visible at 90°K. The measurement on Ce^{3+} in LaF_3 are correlated with the theoretical discussion of Van Vleck and Hebb published in 1934.

Electron spin resonance in two salts containing gadolinium. By J. M. Baker and F. I. B. Williams.
The electron spin resonance spectra of Gd^{3+} have been measured in gadolinium hexa-antipyrene iodide (HAPI), lanthanum HAPI and cadmium fluoride. In CdF_2 the Gd^{3+} ions are sometimes in sites of cubic and sometimes in sites of tetragonal symmetry. In the latter the zero field splitting is remarkably small, being about 0·05 cm^{-1}. In the HAPI there is a large zero field splitting, about 0·98 cm^{-1} overall, and even in the undiluted salt the line width is only about 230 gauss, so that it may be suitable for a zero field maser. An appendix gives a discussion of the general problem of rotation of the frame of reference in which the crystal field is described so that the spin Hamiltonian may be written in a form diagonal in the applied magnetic field. The coefficients have been tabulated for the polynomials involved in the general rotation matrix for the operator equivalents. The polynomials have been plotted as a function of angle. There is also a table of factors to relate some of the untabulated matrix elements of the operator equivalents to the Wigner 3—j symbols.

The radiative capture of protons by neutrons at 50 kev. By N. C. Barford, B. B. Palmer and B. Tallini.
By using an internal lithium deuteride target in the Harwell cyclotron, and 'hardening' the resulting scattered neutrons with polythene, a low intensity beam of neutrons with an energy peak of 50 kev was produced. This beam passed through a 9 cm hydrogen bubble chamber and produced in it reactions of the type

$$n + p \rightarrow d + \gamma$$

which were distinguished by the range–angle distribution of the deuterons from the background of elastic n–p scatters. A cross section of 110 ± 60 μbn was found for the process.

Rotational analysis of the E–X system of silicon monosulphide. By R. F. Barrow, J. L. Deutsch, A. Lagerqvist and B. Westerlund.
The rotational analysis of twenty bands of the E–X system of SiS has been carried out. The system arises from a transition $^1\Sigma^+ - {}^1\Sigma^+$, and unexpectedly, no perturbations have been detected in $E^1\Sigma^+$. Constants (in cm^{-1}) for the state $x^1\Sigma^+$, valid for $0 \leqslant v \leqslant 7$ are as follows:

$T_v = 41743{\cdot}8_v$ $G_v = 406{\cdot}8_v\ (v+\frac{1}{2}) - 1{\cdot}95_2\ (v+\frac{1}{2})^2$,
$B_v = 0{\cdot}2213_v - 0{\cdot}0013_v\ (v+\frac{1}{2}) - l_{+4} \times 10^{-5}\ (v+\frac{1}{2})^2$.

It seems probable that the state E is the $^1\Sigma^+$ state arising from the configuration $\ldots\ldots\sigma^2\sigma^2\pi^4$, analogous to the state $B\ ^1\Sigma_u^+$ of the isoelectronic molecule P_2.

Stable crack propagation in plastics. By J. J. Benbow.
A description is given of apparatus designed to measure the crack propagation energy of plastics under conditions where they are brittle. This includes a brief history of the work leading up to the present studies and details of a novel type of instrument suitable for measurements over a range of temperatures. Use of these techniques is illustrated by typical results on Perspex, polystyrene and polythene.
In addition, some of the interesting features found on the surfaces of cracks are described. The patterns found on cracks in polystyrene are illustrated and their possible origins are briefly discussed. Finally the colours found on freshly formed cracks in Perspex are described.

The electron-voltaic effects in silicon and selenium elements. By E. W. Billington and W. Ehrenberg.
The generation of electric currents by visible light and cathode rays in silicon solar cells and in selenium photo-cells elements is studied experimentally. The variation of electron voltaic current with cathode ray energy in the selenium elements shows that electrons in grey selenium are mobile, their mobility of about 5×10^{-3} $cm^2\ sec^{-1}\ v^{-1}$, playing a major part in the electron voltaic effect.
A fatigue effect of a relaxation time of seconds has also been studied.

A temperature dependent relaxation in a square loop ferrite. By J. R. Chamberlain.
Measurements of the initial permeability of a commercial square-loop ferrite (Ferroxcube D.1) as a function of frequency and temperature are reported. These show the presence of a relaxation which is due to the

damping of domain boundary walls in the material by a process of electron diffusion. It is found that all the domain walls in the material are not affected by this process. The presence of the relaxation does not allow the dynamic characteristics of the domain walls, important in conventional pulsed-reversal experiments, to be determined by the method employed here.

Magnetocrystalline anisotropy and coercivity in a square-loop ferrite material. By J. R. Chamberlain.

It is shown that the first-order magnetocrystaline anisotropy constant (K_1) of a square-loop ferrite material can be determined from measurements of the approach to saturation of magnetization in a polycrystalline specimen. The energy ($\gamma = 0{\cdot}20$ erg cm^{-2}) and the thickness ($\delta = 1{\cdot}6 \times 10^{-5}$ cm) of 180° domain boundary walls in a commercial manganese magnesium ferrite, Ferroxcube D.1, are estimated from results obtained in this way. The temperature variation of coercivity in the same material is also discussed in the light of these results, and it is found that the Goodenough theory of domain creation is inapplicable. Pores were observed in the material. Although these have a diameter greater than the estimated domain wall width δ, the experimental results presented are not consistent with the Néel disperse field theory.

The inversion of specific heat curves. By R. G. Chambers.

It is shown that the methods proposed by Montroll and Kroll for deriving the lattice frequency spectrum from the experimental specific heat curve will in practice yield only a 'smoothed' spectrum, averaged over a range of $1{\cdot}6 \pm 1$ or more in frequency. Any practicable improvement in experimental accuracy will reduce this smoothing only slightly. The same smoothed spectrum can be derived more simply by a procedure involving only one quadrature, and a still simpler trial-and-error method is also described and illustrated.

On the reaction Pt (n, α)Os. By M. W. Cresswell and R. R. Roy.

The reaction Pt(n, α)Os has been investigated by a nuclear emulsion technique, using the thermal neutron flux of the Pennsylvania State University Reactor. A semi-empirical range–energy relationship has been developed for α-particles in platinum and has been used for the evaluation of data. Two groups of alpha particles have been observed with certainty, corresponding to Q-values $6{\cdot}9 \pm 0{\cdot}3$ MeV and $8{\cdot}5 \pm 0{\cdot}3$ MeV and have been identified with reactions ^{192}Pt(n, α)^{189}Os and ^{194}Pt(n, α)^{191}Os respectively. A probable group of alpha particles corresponding to Q-value $12{\cdot}1 \pm 0{\cdot}3$ has been associated with the reaction ^{198}Pt(n, α)^{195}Os.

Electrical properties of organic insulating liquids containing fluorescent solutes. By M. Darvenizia and H. Tropper.

The present work, which is concerned with measurements on highly purified transformer oil and the simple hydrocarbons hexane and benzene, reports a new phenomenon: the excitation of fluorescent solutes in liquids by the application of high electric fields. The characteristics of the light emission have been investigated and its influence on other pre-breakdown processes and on the electrical strength have been determined. Dielectrics showing this effect have been synthesized by dissolving known concentrations of fluorescent materials into simple organic liquids. These have confirmed the experimental results obtained with the more complex transformer oil. Also, experiments are described which show that even highly degassed liquids exhibit pressure dependence if brought into a state of supersaturation by applying tension to the liquid.

Participation of the electron gas in lattice vibrations. Part I. Gold. By B. Dayal and S. P. Singh.

The vibration spectrum and the specific heats of gold have been studied by two models in order to test whether the electrons participate in the lattice vibration spectrum of a crystal. The two models represent the extreme cases given by de Launay, one of which ignores the effect of electrons on the lattice vibration, while the other assumes its full participation for all frequencies. Frequencies have been calculated for the 1000 points of the Brillouin Zone and the specific heats have been evaluated by the sampling technique. The choice of this metal for calculation was dictated by the fact that, on account of largest discrepancy in the Cauchy relation, the difference between the lattice frequencies of the two models is expected to be highest. It is found that the central force model does not interpret the C_v of the metal correctly, while de Launay's model is fairly successful in this respect. De Launay's idea that electrons only participate in the non-dispersive region of the spectrum is shown to be erroneous.

Anisotropy of the electrical conductivity in bismuth telluride. By R. T. Delves, A. E. Bowley, D. W. Hazelden and H. J. Goldsmid.

The anisotropy of the electrical conductivity of Bi_2Te_3 at room temperature has been determined by a four-probe method. The anisotropy ratio for undoped p-type material is close to 3·0; for iodine-doped n-type material it is appreciably higher and increases with the impurity concentration. Measurements of the galvanomagnetic effects in highly-doped n-type Bi_2Te_3 have shown that the observed variation of the anisotropy ratio can be interpreted in terms of a change of shape of the equi-energy surfaces in momentum space with increasing density of charge carriers.

On the electronic conduction in polar semiconductors. By B. Durney.

The Boltzmann equation for polar semiconductors, with the collision operator derived by Howarth and Sondheimer, is solved formally.

For the non-degenerate and degenerate limits and for low and high temperatures exact solutions of the Boltzmann equation are compared with approximate ones.

Expressions for the conductivity are derived with the help of these approximate solutions.

Controlled reaction between active nitrogen and methylene chloride. By S. N. Ghosh, A. Sharma and Sharda Nand.

Controlled reaction between active nitrogen and methylene chloride is performed in a dynamical flow system. The nitrogen is activated by microwave discharge from an oscillator operating at a frequency of 2450 Mc/s. The spectrum of N_2 discharge shows the first and second positive systems of N_2, first negative system of N_2^+ and some atomic lines. The spectrum of the glow produced by the reaction between active nitrogen and methylene chloride shows red and violet systems of CN and one band of CH at 4312 Å. The intensity variation of a CN band with the partial pressure of CH_2Cl_2 is photometrically studied and the cross section of quenching of excited CN by CH_2Cl_2 is found to be $1{\cdot}8 \times 10^{-14}$ cm^2.

The mass-spectrometric analysis of the gas taken from the region where glow occurs shows HCl as one of the final products of the reaction. The mechanism of the reaction is discussed.

The absorption of ozone in the ultra-violet and visible regions of the spectrum. By A. G. Hearn.

The absorption coefficient of gaseous ozone has been measured for the mercury lines at 2537, 2894, 2967, 3021, 3342 and 5770 Å by measuring the optical absorption and the pressure as the ozone decays in a sealed quartz absorption tube. This avoids the chemical determination of the ozone. The determination gives independent and absolute values of the absorption coefficients, and their standard deviations are 2½% or less. Previous measurements of the absorption coefficients disagree by as much as 25%, but the present results generally agree within the limits of error with those of Inn and Tanaka.

Intensity measurements in emission on 29 bands of the O_2 Schumann-Runge system. By G. R. Hébert and R. W. Nicholls.

Relative integrated photoelectric intensity measurements have been made upon each of the $v' = 0$, $v'' = 9$–19; $v' = 1$, $v'' = 8$–12; 2, 16–20; $v' = 2$, $v'' = 7$–9, 15, 16, 19–21, bands of the Schumann–Runge system. These measurements have been interpreted, with the aid of Franck–Condon factors $q_{v'v''}$ and r-centroids $r_{v'v''}$, to determine the variation of electronic transition moment $R_e(r)$ with internuclear separation r as

$R_e(r) = \text{const.} \cdot (1 - 1{\cdot}1807r + 0{\cdot}35047r^2)$ 1·44(Å) $< r <$ 1·76(Å).

A 'smoothed' array of relative vibrational transition probabilities $p_{v'v''} = q_{v'v''}r_{v'v''}^4/q_{v'v''}r_{v'v''}^4$ and band oscillator strengths $f_{v'v''}$ have thereby been determined for all bands of the system between 2450Å and 5000Å.

The excitation of the vibrational modes of ethylene in homomolecular collisions. By R. Holmes and W. Tempest.

Sound absorption and velocity were measured in ethylene at 500 kc/s and 700 kc/s in the ranges 0·07 atm to 2 atm and − 10°c to 80°c. All the vibrational modes relaxed out at approximately 1 Mc/s atm, but the assumption of two relaxation times for the transfer of energy between translational and vibrational motion fitted the measurements better than the assumption of a single relaxation time. Assuming that the average relaxation time found by fitting single relaxation curves to the measured points was approximately that of the lowest frequency mode, the value of the force constant β in the exponential intermolecular potential was found to be $6{\cdot}71 \cdot 10^8$ cm^{-1}. This agrees well with the value $4{\cdot}72 \cdot 10^8$ cm^{-1} calculated from the Lennard-Jones potential.

Radio-wave scattering from the lunar surface. By V. A. Hughes.

This paper describes some recent measurements on the angular scattering properties of the lunar surface at the wavelength of 10 cm. The scattering law of the surface is shown to be $P(\theta) = a_n \exp\{-10{\cdot}2\theta\}$ over the range of θ from 4° to 13°, and a comparison with other results shows that it is independent of wavelength up to $\lambda = 1{\cdot}5$ metres. For angles up to 30° the scattering law deviates from an exponential but is still independent of wavelength up to at least $\lambda = 75$ cm. Evidence is given to show that the surface may be considered as rough at radio wavelengths.

Low energy elastic scattering of neutrons by deuterons. By J. W. Humberston.

Neuteron–deuteron scattering phases are evaluated at five energies below 8 MeV for two ranges of a central Yukawa interaction. The dependence of the phases on the range is found to be very slight. Differences are found between these results and those reported by Haas and Robertson in 1959 who used the same form of interaction with the shorter of the two ranges considered here. The results and subsequent discussion resolve some previously inexplicable differences between the scattering lengths obtained with various potential shapes.

Thermally stimulated emission and conductivity peaks in the case of temperature dependent trapping cross sections. By P. N. Keating.

The original theory of thermally stimulated emission is extended to include the effect of a temperature dependent trapping cross section. A method is proposed whereby the ionization energy and temperature dependent capture cross section of a set of identical trapping states may be determined from the half-width and shape of a thermally stimulated emission or current peak obtained from a single experiment.

The nature of the abrasion process in plastically deformable non-metals. By J. N. King and H. Wilman.

The friction, wear and surface deformation in abrasion of typical very plastic non-metallic materials, AgCl and AgBr, are investigated on emery papers at 200–500 g load. They are strikingly similar in form and magnitude to those for metals of comparable hardness. The wear rate M is related linearly to the friction coefficient μ, when the emery particle diameter D is greater than 70 microns, but on finer abrasive the M/μ locus curves to lower μ, as for soft metals.

Optical microscopic study of single abrasion grooves shows the wear to be mainly by a cutting action like that of a lathe tool, but that much plastic flow occurs; and it indicates a high adhesion component of the friction.

Electron diffraction shows a backwardly tilted {110} orientation in the abraded surface region. Its form, and its preferred azimuthal range, shows its close relation to the rolling texture, and to the compression texture when extensive lateral flow is permitted. The correlation between the tilt δ of the orientation axis from the specimen normal, with μ, is discussed.

Grain boundary damping. Part I. Pure Iron. By G. M. Leak.

Internal friction measurements have been carried out on specimens of high purity iron from which carbon and nitrogen have been removed. A relaxation peak, observed at about 500°c for a frequency of vibration about 1 c/s, is associated with the presence of grain boundaries in the specimens. The activation energy Q associated with this damping process is 46 kcal mol^{-1}. The variation of peak damping and background damping is similar to that observed in other pure metals. The damping appears to be governed by a term frequency, $(\text{grain size})^3 \exp(Q/RT)$.

Grain boundary damping. Part II. Iron-interstitial alloys. By G. W. Miles and G. M. Leak.

Internal friction measurements of the grain boundary relaxation peak have been carried out on alloys of high purity iron containing carbon or nitrogen. The influence of these impurities on peak height, peak temperature and on the activation energy for the mechanism giving rise to the damping have been determined. The results differ from those reported on the influence

of substitutional impurities. The explanation of these effects is discussed qualitatively in terms of the boundary sliding and boundary migration mechanisms.

Microwave measurement of attachment in oxygen-nitrogen mixtures. By J. J. Lennon and M. J. Mulcahy.
A microwave cavity method has been used to measure the electron loss rate following a pulsed discharge in oxygen–nitrogen mixtures. Preliminary results indicate that, when suitable pressures of oxygen and nitrogen are chosen, the main mechanism of electron removal in the later afterglow is a three-body attachment process. The three-body coefficient $K = 2{\cdot}4 \times 10^{-27}$ cm^6 sec^{-1} is in good agreement with the drift tube measurements, for thermal electrons, of Chanin *et al.*

The specific heat of hexagonal metals at very low temperatures. By D. L. Martin.
The specific heats of cadmium and magnesium have been measured in the temperature range 0·4° to 1·5°K. For cadmium the electronic specific heat coefficient γ is 163·6 ±2·6 μcal deg^{-2} (g at.)$^{-1}$, the Debye temperature θ is 204 ± 3°K, and the superconducting transition temperature is 0·52 ± 0·01°K. For magnesium γ is 292·7 ±2·5 μcal deg^{-2} (g at.)$^{-1}$. These results show that a previously reported discrepancy between the elastic and thermal values of θ for the hexagonal metals was due to incorrect interpretation of specific heat data.

The low temperature specific heat of an aluminium-manganese alloy. By D. L. Martin.
Aluminium–manganese alloys do not show the resistance–minimum phenomena often found in dilute alloys containing transition metals, but anomalous thermoelectric powers are observed. Alloy systems which do show the resistance minimum also have large specific heat anomalies at low temperatures. It was therefore of interest to see whether specific heat anomalies occurred in the aluminium–manganese system.
Measurements of the specific heat of pure aluminium and of an alloy containing 0·045 atomic per cent manganese were therefore made in the temperature range 0·4° to 1·5°K. In the normal state the specific heats of the two samples are the same. Thus a specific heat anomaly of the type found in systems showing the resistance minimum does not occur. The superconducting transition temperature of the alloy is about 0·84°K (compared with 1·174 ±0·002°K for pure aluminium) but the transition remains sharp (width less than 0·001°K) and of the second order. The electronic specific heats in the superconducting state, when given in terms of reduced temperature (T_c/T), are identical.

The lifetime of the 673 kev level in ^{131}Xe. By W. D. Hamilton.
The resonant scattering cross section for the 673 kev electric quadrupole transition in ^{131}Xe was directly determined for a particular arrangement of source, scatterer and detector. The resonant scattering condition was provided by the persistence of nuclear recoil following a preceding transition when the source was in the gaseous phase. The differential cross section for a mean scattering angle of 149° was evaluated as $\sigma\,(149°) = 1{\cdot}75 \times 10^{-18}$ cm^2 sterad^{-1}, and the value $\tau = (9{\cdot}7 \pm 3{\cdot}0) \times 10^{-12}$ sec was found for the mean life of the level. This result is in good agreement with that obtained from a Coulomb excitation measurement. The enhancement of the E2 transition probability when represented by the ratio $B(\mathrm{E2};\ \mathrm{O} \rightarrow 2)/B(\mathrm{E2})_{\mathrm{s.p.}}$, has the value 20; this is consistent with the results for even–even nuclei which have a characteristic vibrational spectra.

The scattering of waves by dislocations. By F. R. N. Nabarro and J. M. Ziman.
An exact solution is given for scattering by the potential ρ^{-1} in two dimensions. This is compared with the results of the first and second Born approximations for the same potential in an analysis similar to that of Dalitz for the Coulomb potential r^{-1} in three dimensions. Seeger and Bross have shown that the second-order terms in the scattering of conduction electrons by an edge dislocation diverge logarithmically as the radius of the cylinder in which the potential of the dislocation is assumed to act increases. Similar logarithmic terms appear in the second Born approximations for the potentials r^{-1} and ρ^{-1}, and, following Dalitz, reasons are given for believing that they represent a phase shift produced by the refraction of the incident and scattered waves, and that they do not contribute to the scattered amplitude. The cross sections for scattering by a dislocation are probably never much greater than those given by the first Born approximation, and may even be smaller. It is not possible to obtain the large values suggested by some experimental observations.

On the momentum spectrum of cosmic-ray muons at sea level. By A. L. Rodgers.
The Manchester spectrum of muons arriving vertically at sea level reported by Holmes *et al.* in 1961 is discussed in terms of the processes leading to the formation of the sea level hard component of cosmic radiation. Evidence is presented to show that above a momentum of 20 Gev/c there are muons at sea level which cannot be explained in terms of π–μ decay only.

Multiplet production by x-rays. By R. R. Roy, C. H. Blanchard, E. H. Webb, H. S. Sandhu and R. C. Mohanty.
Ilford G-5, 400μ thick nuclear emulsion plates were bombarded by hardened x-ray beam of energy 5–90 mev. Altogether 34 433 fields of view were examined, the volume of each field of view being 120μ × 150μ × 220μ. A total of 21 887 pairs, 1935 triplets, 106 quartets, 10 quintets and one sextet have been observed. Frequency of occurrence of multiplets (quartets, quintets and sextet) together with the energy distribution of the small energy partners of the multiplets have been presented. Possible explanations of the origin of multiplets have been discussed.

Variation of Townsend's second coefficient in electrodeless discharge. By S. N. Sen and A. K. Ghosh.
The variation of γ, the second Townsend coefficient, in an electrodeless discharge has been studied in air with discharge tubes of different lengths within the pressure range of 1μ to 1000μ. It is found that γ varies with pressure and also with (E/p) as in case of d.c. discharge. The graph of γ against (E/p) shows that γ is large for both low and high pressures and remains constant over a certain region of pressure near the value for minimum breakdown voltage. It is assumed that in case of electrodeless discharge, and within the range of pressure used in the experiment, γ arises due to four distinct causes, that is, due to electrons striking the glass surface, the positive ions striking the glass surface, the ionization by positive ions, and lastly due to photo-ionization. A mathematical derivation has been provided for the variation of γ with (E/p). The mathematical expression thus deduced agrees with the nature of the curve regarding the variation of γ with (E/p) as obtained experimentally.

Dispersion relations for superconductors. By A. W. B. Taylor.
The general macroscopic description of the electromagnetic behaviour of superconductors and normal conductors is developed, and dispersion relations for the frequency dependent material functions are rigorously established. From these dispersion relations expressions similar to the usual sum rules of electromagnetic theory are derived. Using these, the proof given by Ferrell in 1959 that the Meissner effect is a consequence of the energy gap is shown to be incorrect. Using the complex surface impedance, it is shown macroscopically that as a consequence of the Meissner effect the area under the absorptivity curve for a superconductor is less than for the normal state.

The infra-red Faraday effect in germanium. By A. K. Walton and T. S. Moss.
Measurements of the infra-red Faraday effect have been made in n-type, p-type and intrinsic germanium. The Faraday rotations observed are interpreted as being due to free electrons in n-type germanium, valence to conduction band transitions in intrinsic germanium, and light and heavy holes and intervalence band transitions in p-type germanium. The rotations obtained for variously doped n-type specimens are used in conjunction with Hall effect measurements on the same specimens to evaluate the Hall scattering constant as a function of the impurity content. In p-type material the rotations obtained are used to determine the relative population of the light and heavy hole states.

Interferometric measurements of the electron density in a shock heated deuterium plasma. By J. K. Wright, R. D. Medford, A. G. Hunt and J. D. Herbert.
The first results are reported of experiments new to plasma research, namely time-resolved interferometry in the optical region. It is shown how the electron density distribution of a fast cylindrical pinched discharge may be measured and how the physical conditions in the discharge may be deduced from such measurements.

LETTERS TO THE EDITOR

The optical absorption edge of gallium arsenide. By M. V. Hobden and M. D. Sturge.

Scattering by the screened Coulomb potential. By B. L. Moiseiwitsch.

Double beta decay. By H. Primakoff and S. P. Rosen.

RESEARCH PROBLEMS ONLY YOU CAN SOLVE

We have vacancies in our central Mechanical Engineering Laboratory for theoretical and experimental research workers: Physicists, Mathematicians and Engineers. They offer you opportunities to work on fundamental topics relevant to a wide range of interests. (Close contact with University and similar groups and the writing of scientific papers are encouraged.) The equipment is excellent and for computation two DEUCE digital computers and analogue computers, including one with over 1,500 amplifiers, are available. The Department will shortly have access to the new fast computer KDF9 with an ALGOL translator.

There are specific openings for a

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to join a team which is at present engaged in solving partial differential equations associated with field problems, and which also provides a service on specialist computational problems.

The posts are permanent and applicants should be of good honours degree standard. Assistance will be given both with moving and with house purchase.

Applications should be addressed to the Technical Staff Officer, Dept. G.P.S. English Electric House, Strand, London, W.C.2, quoting reference BP.1916G, where enquiries will be treated in strictest confidence.

Analogue Computer Analyst

to investigate the application of large electronic analogue computers to the solution of mechanical engineering problems.

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to carry out fundamental theoretic work on the performance and distortion of various types of thrust and journal bearings. There will be close liaison with the engineers concerned with the experimental aspects of such problems.

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to undertake research into fundamentals of vibration particularly associated with steam and gas turbines and other products of the Company. Opportunities arise to act in a consultative capacity to the product divisions.

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Physicist or Engineer

to investigate the mechanism of friction and wear under unlubricated or partially lubricated conditions.

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interested in applying the techniques of electron microscopy, X-ray and electron diffraction to problems in metal physics.

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SPACE RESEARCH including radio and visual observations on SATELLITES: Calculation and prediction of orbital information, and development of instruments for use in Satellites to study characteristics of ATMOSPHERE and OUTER SPACE (Scientific Officer).

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Basic investigations of OPTICAL SYSTEMS in INFRA-RED and PHOTOGRAPHIC OPTICS (Scientific Officer or Senior Scientific Officer).

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Department of Physics

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Lecturers £1,370–£1,550

Further particulars and forms of application from the Bursar, College of Advanced Technology, Gosta Green, Birmingham, 4. Applications to be received within 14 days of this advertisement. Please quote "V".

K. R. PILLING,
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Applicants for these posts are not expected to have special knowledge of footwear. Starting salaries will depend on age, qualifications and experience and will be such as to attract applicants of ability. *Full details of either post, including prospects, sent on request.* Write, in confidence, giving brief particulars, to Director of Research, Satra House, Rockingham Road, Kettering, Northants.

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Appointment normally five years in first instance.

Outfit allowance £G60. Car allowance £G150 p.a. Family allowance for non-Ghanaians for each child in West Africa £G50 p.a. or, if under age of 21 and being educated outside West Africa, £G100 p.a. (maximum 5 children). Part furnished accommodation at charge not exceeding 7·5% of salary. F.S.S.U. policies maintained if already held, or superannuation on similar basis.

Passages for appointee and family on appointment and normal termination. Annual leave with 3 overseas return passages in every 4 years for non-Ghanaians and one every three years for Ghanaians.

Applications (six copies) with full details of qualifications, experience, etc., and naming three referees to be sent before September 25, 1961, to the **Assistant Registrar (London), University of Ghana, 15 Gordon Square, London, W.C.1,** from whom further information may be obtained.

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SIR THOMAS LYLE FELLOWSHIP IN PHYSICS

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EXPERIMENTAL OFFICER required by ROYAL MILITARY COLLEGE OF SCIENCE, SHRIVENHAM, BERKSHIRE, to provide for testing, maintenance, calibration and repair of nuclear electronic apparatus, and maintenance of high intensity radiation generators. Opportunity to assist in research work. Candidates should have considerable experience with electronic equipment or, preferably, nucleonic equipment. Qualified man encouraged to do personal research for higher degrees. Qualifications: G.C.E. (A level), Pass degree, H.N.C. or equivalent. Salary: £1,057–£1,336. Starting salary allows credit for approved postgraduate experience and National Service. Opportunity for establishment and promotion. Quarters available for single man, possibility of house for married man. Forms from Ministry of Labour, Technical and Scientific Register (K), 28 King Street, London, S.W.1, quoting reference A.253/1A.

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Applications are invited for the post of senior Research Assistant for a programme of work on the magnetic properties of thin films. The appointment is for one year in the first instance. Applicants should be of Ph.D. standard. Salary according to age and experience with F.S.S.U. benefits if required. Applications, which should include a statement of qualifications and the names of not more than three persons to whom reference may be made, should be sent to the Principal, Royal Holloway College, (University of London), Englefield Green, Surrey, as soon as possible.

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a Company associated with a major group in the telecommunications field, requires ENGINEERS AND PHYSICISTS for work in the development, production control and application of valves, cold cathode tubes and similar devices. Previous experience in these fields would be an advantage but is not essential. Vacancies exist for both senior and junior staff. The posts are pensionable and offer considerable scope for advancement. Applications, which will be treated in strict confidence, should be addressed to: The Engineer-in-Chief, Hivac Limited, Stonefield Way, Victoria Road, South Ruislip, Middlesex.

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Candidates should possess at least an H.N.C. in Physics, or equivalent qualification.

The salary will be within the range of £895–£1,015 per annum and there are excellent conditions of service.

Applications, giving details of age, qualifications and experience, should be addressed to the

Industrial Relations Officer,
West Midlands Gas Board,
6 Augustus Road, Edgbaston,
Birmingham, 15

Central Electricity Generating Board

PHYSICS DIVISION

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